

JOHN JAMES AUDUBON
1785-1851

From a portrait in oil by George P. A. Healy, London, 1838.

Courtesy of M. Ruthven Deane.

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BIOLOGY IN AMERICA

R. T. YOUNG

WITH MORE THAN
TWO HUNDRED ILLUSTRATIONS



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To
THE MEMORY OF
MY MOTHER

PREFACE

To the "man in the street" the biologist, with his "bugs" or his "germs," frequently appears as a harmless but equally useless individual. Thus in an issue of the "New Republic," shortly after America's entrance into the world war, a serio-comic writer in criticizing the action of President Wilson in appointing a committee on national preparedness from the National Academy of Sciences says, "I doubt if any other nation ever responded to the prospect of war with a scheme of national defense which included a Committee on Zoölogy and Animal Morphology."

What excuse then has the biologist for his existence? What can he say for the "truth that is in him"?

When half a century ago the Austrian monk, Gregor Mendel, was "puttering" over his sweet peas in the garden of the monastery at Brünn in the Tyrol, the world took small notice of his work, little realizing that he was laying the foundation stones of a science which was to place animal and plant breeding on a scientific basis, and teach us how to build a better race of man himself. When the English army surgeon Ross in India in 1898 was studying a microscopic organism in the blood of the owl, he could not foresee that his work would in a few years' time virtually abolish malaria in Ismailia on the Suez Canal, where in 1902 there were 1548 cases in a population of about 6,000; that it would render possible the building of the Panama Canal, and convert Havana into a health resort.

Of what particular practical importance was Harrison's discovery that a bit of nerve cord transferred from a tadpole to a drop of frog's lymph would develop nerve fibres there? Yet Harrison's method of making that discovery has opened to science an entirely new field in the study of tissue growth, both benign and malignant, has enabled us to observe the growth of the cancer cell, and determine some of the conditions of that growth, and may some day lead us to a solution of the cancer problem.

When a fish embryo is developed in a solution of magnesium chloride it gives rise to various malformations, most conspicuous of which is the "cyclopean eye." Of what possible value to a workaday world is such a discovery? Very little in

itself. But if the young fish can be distorted into all sorts of monstrous shapes by chemical treatment, why may not the monstrosities observed in man, some of which are not necessarily fatal, but which entail on their victims sorrow and suffering, be due to a similar cause? And may not the discovery of the cause lead to its control?

But the primary aim of science is not utilitarianism. Were this so, it would still be wearing rompers instead of seven league boots. It is a commonplace to say that the aim of science is truth, regardless of what practical value such truth may have. But the "man in the street" frequently fails to realize the connection between purpose and accomplishment in science. Perhaps never has this relation been made more clear than in the recent war. The German Government, recognizing the value of science for its own sake, encouraged it with every means in its power, and the German university became a Mecca for scientific students throughout the world. England, on the contrary, was more interested in developing good cricketers and diplomatists than in training scientists, and when war came upon her "like a thief in the night" she found herself under a well-nigh fatal handicap.

It was farseeing statesmanship which led President Wilson to call for a council of national defense from the National Academy of Sciences on America's entrance into the war. It would have been still farther sighted had this council been established long years ago.

American biology, with the lusty vigor of youth, has advanced by leaps and bounds in recent years; and today a wonderful future opens before it. From the days when the early naturalists went hand in hand with the pioneer into the depths of our great forests, crossed the boundless prairie and pierced the trackless labyrinth of mountain peak and canyon, to the present, when the names of American biologists stand throughout the world as synonyms of biological progress, their record is one of which our nation and the world may well be proud.

It is in the hope of recording, in some small measure, the story of this progress that this book is written. Most of the facts herein recorded have already appeared in the many books dealing with the biological problems of the last few years, but nowhere, so far as I know, has a brief, comprehensive and simple story of the work of American biologists been told. It is in the hope of presenting such a story that this work has been undertaken. To give a comprehensive as well as simple account of so complex a field as biology is, however, far from easy. A full account of so wide a field would require many volumes, but I shall attempt to touch only

upon the more salient points. The avoidance of technical terms is in many cases impossible, but I have endeavored to reduce them to a minimum.

It is of course impossible in such a story to avoid referring to the work of biologists in other lands. Nor is it desirable. Science is not bounded by political and racial lines, and the work of American biologists can only be appreciated in the light of what their colleagues in other lands have been doing. The book is, however, a record of American biology, so that reference to the work of other biologists will be only incidental to the main trend of the story.

A zoölogist should perhaps apologize for the title, since the main emphasis will naturally fall on that branch of biology with which he is most familiar. The great principles of life, however, apply equally to plants and animals, and even though the examples which illustrate these principles have been drawn mainly from the animal world, nevertheless the title will be justified if the discoveries recorded are those which in the main illustrate the laws which govern plants and animals alike.

The writer is indebted to numerous sources for the illustrations and quotations found in this book. Due acknowledgment for each is made in connection with it.

To his wife, Ellen F. P. Young, and sister, Mary Farrar, grateful acknowledgment is due for assistance with the proof and index.

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BIOLOGY
IN AMERICA

BIOLOGY IN AMERICA

CHAPTER I

Work of the early biologists. Explorers and travelers, collectors, field naturalists and museum men. Early surveys, state and national.

The evolution of human thought parallels that of the individual mind. Man sees first the effect and then seeks the cause. The falling apple pointed the way to the discovery of the law of gravitation; the amber wand, when rubbed with a bit of fur, to the discovery of electricity, and the "pebrin" disease of the silkworm to the modern science of bacteriology. The story of all science is one of observation of phenomena, speculation as to their cause, and finally the determination of cause by means of experiment. The recording of phenomena is not however limited to any given scientific age, but necessarily goes hand in hand with philosophy and experiment, forming with them the trinity of scientific progress.

It is but natural, then, that the early history of biology in America should be written in the bold characters of stirring adventure. Across the sea in the first years of the last century came adventurous spirits, keen-eyed and lusty hearted, with the "call of the wild" in their souls. Some of these, like the Scotch peddler Wilson, and the eccentric Audubon were "ne'er do weels" filled with the primitive instinct of the nomad. Others were men of high station in the Old World, like Lucien Bonaparte, nephew of the great imperialist, who came to this country, like their humbler comrades, impelled by a spirit of scientific adventure. There were still other naturalists in the early days in America, like the Bartrams, who were natives of the soil.

These early biologists were naturally collectors and field naturalists, but with the establishment of learned societies they were soon joined by museum men, who worked up the material collected in the field. The interest of these latter, then as now, was primarily in classification and distribution, but the writings of the field naturalists are replete with interesting accounts of the homes and habits of the animals

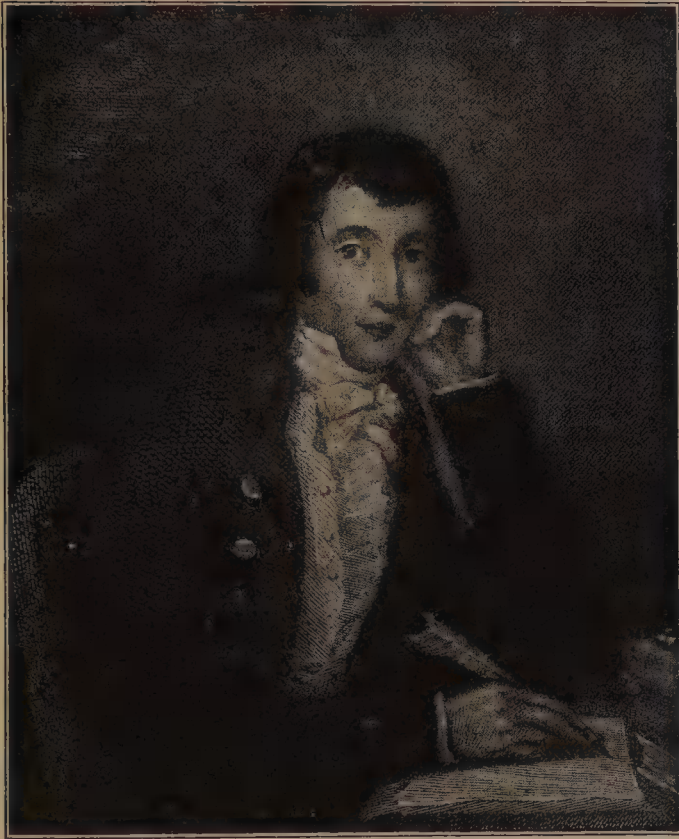
and plants which they collected. Oftentimes collector and classifier were the same, as with Baird, Coues and many others.

On the banks of the Schuylkill River in Philadelphia stands an old stone mansion, over which the pleasant ivy clammers, and in the garden round about, now a city park, are still growing many of the plants set out there nearly two centuries ago by John Bartram, who was the first American botanist of note, and whose garden, laid out in 1728, was the first botanical garden in America. His old rock wine press is there still, from which the host provided refreshment for Washington, Franklin, Hancock, Rittenhouse, Morris and many others whose names are written large on the pages of our nation's story; and to his home also came many notables from abroad, for his reputation for learning and hospitality was well known. Bartram acted at one time as American botanist to George III, and corresponded with Linnæus, who considered him "the greatest natural botanist in the world," as well as with other leading European naturalists of his time, with whom he exchanged many plants for the books which could only be obtained in Europe. Provided with independent means, he made extensive journeys through eastern America, from Lake Ontario to Florida, in search of plants, accounts of which were published by him, as well as several minor papers on natural history.

Here was born and died the son, William, a botanist and ornithologist of note. Like his father, he was an extensive traveler, and published an account of his travels, as well as a list of American birds, which was the first extensive work on American ornithology.

Over the counter of a little store in Louisville, Kentucky, there occurred in March, 1810, a chance meeting between two men who have stamped their names in indelible letters on the pages of American Science. They were Alexander Wilson, the Scotch weaver, and John James Audubon, the French artist. In his "Ornithological Biography," Audubon has given us an interesting account of this meeting and of his impressions of his co-worker in the field of ornithology. "One fair morning," writes Audubon, "I was surprised by the sudden entrance into our counting-room at Louisville of Mr. Alexander Wilson, the celebrated author of the *American Ornithology*, of whose existence I had never until that moment been apprised. This happened in March, 1810. How well do I remember him as he then walked up to me! His long, rather hooked nose, the keenness of his eyes, and his prominent cheek-bones, stamped his countenance with a peculiar character. His dress, too, was of a kind not usually seen in

that part of the country; a short coat, trousers, and a waist-coat of grey cloth. His stature was not above middle size. He had two volumes under his arm, and . . . immediately proceeded to disclose the object of his visit, which was to procure subscriptions for his work. . . . It happened that he lodged in the same house with us, but his retired habits, I thought, exhibited either a strong feeling of discontent or a



ALEXANDER WILSON

From a painting by James Crow.

Courtesy of Mr. Ruthven Deane.

decided melancholy. The Scotch airs which he played sweetly on his flute made me melancholy, too, and I felt for him. I presented him to my wife and friends, and seeing that he was all enthusiasm, exerted myself as much as was in my power to procure for him the specimens which he wanted. We hunted together, and obtained birds which he had never seen before; but, reader, I did not subscribe to his work, for, even at that time, my collection was greater than his. . . .

Some time elapsed, during which I never heard of him, or of his work. At length, having occasion to go to Philadelphia, I, immediately after my arrival there, inquired for him, and paid him a visit, (but) . . . feeling, as I was forced to do, that my company was not agreeable, I parted from him; and after that I never saw him again. But judge of my astonishment some time after when, on reading the thirty-ninth page of the ninth volume of *American Ornithology*, I found in it the following paragraph:

“ ‘March 23, 1910. I bade adieu to Louisville, to which place I had four letters of recommendation, and was taught to expect much of everything there; but neither received one act of civility from those to whom I was recommended, one subscriber, nor one new bird; though I delivered my letters, ransacked the woods repeatedly, and visited all the characters likely to subscribe. Science or literature has not one friend in this place.’ ”¹

Alexander Wilson, the “father of American ornithology,” was born at Paisley, Scotland, on July 6, 1766. He was the son of a weaver, who, together with his regular trade, combined farming, distilling and smuggling. Destined by his parents for the church, his studies in this direction were early terminated by various vicissitudes in the Wilson family, such as the advent of a step-mother and sundry children, and the young Wilson became a weaver apprentice, from which pursuit his rambling propensities soon diverted him into the paths of the peddler and poacher. Indulging himself in a little fun at the expense of the master weavers during a trade dispute, he paid penance therefor with a brief sojourn in jail, after which he emigrated to America in 1794. Here he earned a precarious living as peddler, printer, and school teacher, the latter profession seeming to have stood as high in public esteem then as now, until he made the acquaintance of the younger Bartram and the engraver Lawson, under whose advice and encouragement he gave himself up to his passion for natural history and learned to draw the objects of his search. He now devoted himself to the preparation of his “*American Ornithology*,” in the course of which he roamed the wilderness of the then West, crossing the Alleghanies, sailing down the Ohio, sleeping under the stars or in the frontiersman’s “shack.” In the course of these journeys “in search,” as he says, “of birds and subscribers,” he made the acquaintance of Audubon in the manner above described. The first volume of his work appeared in 1808 and six others followed prior to his early death in 1813, as the result of

¹ Audubon’s *Ornithological Biography*, quoted in “*Life of Audubon*,” pp. 22-24.

hardship and exposure incurred while seeking the birds he loved so well.

To the careful observation of the scientist, Wilson joined the literary enthusiasm of poet and nature lover. His account of the passenger pigeon is full of fascinating interest.

"In descending the Ohio by myself in the month of February, I often rested on my oars to contemplate their aerial manœuvres. A column eight or ten miles in length would appear from Kentucky, high in air, steering across to Indiana. The leaders of this great body would sometimes gradually vary their course, until it formed a large bend of more than a mile in diameter, those behind tracing the exact route of their predecessors. This would continue sometimes long after both extremities were beyond the reach of sight; so that the whole, with its glittery undulations, marked a space on the face of the heavens resembling the windings of a vast and majestic river. When this bend became very great, the birds, as if sensible of the unnecessary circuitous course they were taking, suddenly changed their direction; so that what was in column before became an immense front, straightening all its indentures until it swept the heavens in one vast and infinitely extended line. Other lesser bodies also united with each other as they happened to approach, with such ease and elegance of evolution, forming new figures, and varying these as they united or separated, that I was never tired of contemplating them. Sometimes a hawk would make a sweep on a particular part of the column, from a great height, when almost as quick as lightning that part shot downwards out of the common track; but soon rising again, continued advancing at the same height as before. This inflection was continued by those behind, who on arriving at this point dived down almost perpendicularly to a great depth, and rising, followed the exact path of those that went before. As these vast bodies passed over the river near me, the surface of the water, which was before smooth as glass, appeared marked with innumerable dimples, occasioned by the dropping of their dung, resembling the commencement of a shower of large drops of rain or hail.

"Happening to go ashore one charming afternoon to purchase some milk at a house that stood near the river, and while talking with the people within doors, I was suddenly struck with astonishment at a loud rushing roar, succeeded by instant darkness; which on the first moment I took for a tornado, about to overwhelm the house and everything around in destruction. The people, observing my surprise, coolly said, 'It is only the pigeons;' and on running out, I beheld a flock thirty or forty yards in width sweeping along very low,

between the house and the mountain or height that formed the second bank of the river. These continued passing for more than a quarter of an hour, and at length varied their bearing so as to pass over the mountain, behind which they disappeared before the rear came up."

And these lines from his verses to the bluebird are full of the sweet freshness of the out-of-doors, and bring back to our minds the days of our care-free, bare-foot, boyhood:

"Then loud-piping frogs make the marshes to ring;
Then warm glows the sunshine, and fine is the weather;
The blue woodland flowers just beginning to spring,
And spicewood and sassafras budding together:"

"The slow lingering schoolboys forget they'll be chid,
While gazing intent as he warbles before them
In mantle of sky-blue, and bosom so red,
That each little loiterer seems to adore him."²

A charming picture of Wilson has been given us by James Lane Allen in his "Kentucky Warbler," where we see him, traveling twelve hundred miles on foot through the wilderness to visit Niagara Falls and reaching "home 'mid the deep snows of winter with no soles to his boots." And again as he sets forth on his solitary voyage down the Ohio:

" . . . It is the twenty-fourth of February: the river, swollen with the spring flood, is full of white masses of moving ice. . . . They warned him of his danger, urged him to take a rower, urged him not to go at all. Those who risked the passage of the river floated down on barges called Kentucky arks, or in canoes hollowed each out of a single tree, usually the tulip tree, which you know is very common in our Kentucky woods. But to mention danger was to make him go to meet it. He would have no rower, had no money to hire one, had he wished one. He tells us what he had on board: in one end of the boat some biscuit and cheese, a bottle of cordial given him by a gentleman in Pittsburgh, his gun and trunk and overcoat; at the other end himself and his oars and a tin with which to bail out the skiff, if necessary, to keep it from sinking and also to use as his drinking-cup to dip from the river.

"That February day—the swollen, rushing river, the masses of white ice—the solitary young boatman borne away

²Quotations from the "Passenger Pigeon" and the "Bluebird" in the "American Ornithology."

to a new world on his great work: his heart expanding with excitement and joy as he headed toward the unexplored wilderness of the Mississippi Valley.

"Wondrous experiences were his: from the densely wooded shores there would reach him as he drifted down the whistle of the red bird—those first spring notes so familiar and so welcome to us on mild days toward the last of February. Away off in dim forest valleys, between bold headlands, he saw the rising smoke of sugar camps. At other openings on the landscape grotesque log cabins looked like dog-houses under impending mighty mountains. His rapidly steered skiff passed flotillas of Kentucky arks heavily making their way southward, transporting men and women and children—the moving pioneers of the young nation: the first river merchant-marine of the new world; carrying horses and plows to clearings yet to be made for homesteads in the wilderness; transporting mill-stones for mills not yet built on any wilderness stream. . . .

"He records what to us now sounds incredible, that on March fifth he saw a flock of parroquets. Think of parroquets on the Ohio River in March! . . . Once he encountered a storm of wind and hail and snow and rain, during which the river foamed and rolled like the sea and he had to make good use of his tin to keep the skiff baled out till he could put in to shore. The call of wild turkeys enticed him now toward the shore of Indiana, now toward the shore of Kentucky, but before he reached either they had disappeared. His first night on the Kentucky shore he spent in the cabin of a squatter and heard him tell tales of bear-treeing and wildcat-hunting and wolf-baiting. All night wolves howled in the forests near by and kept the dogs in an uproar; the region swarmed with wolves and wildcats 'black and brown.'

"On and on, until at last the skiff reached the rapids of the Ohio at Louisville and he stepped ashore and sold his frail savior craft, which, at starting, he had named the Ornithologist. The Kentuckian who bought it as the Ornithologist accepted the droll name as that of some Indian chief. He soon left Louisville, having sent his baggage on by wagon, and plunged into the Kentucky forest on his way to Lexington.³

After Wilson's death, the remaining volumes of his work were completed by his friend, Charles Lucien Bonaparte, the Prince of Cannino and nephew of Napoleon, who in early

³ From the "Kentucky Warbler," pp. 82-88, by permission of the author and Doubleday, Page and Co.

life came to America, where he gained reputation as an ornithologist.

The other of these two remarkable men, while an American by birth, was French by parentage and education. Born in Louisiana in 1780, his family shortly after removed to the estate of Aux Cayes in St. Domingo, where his mother was killed in the insurrection of the blacks in 1791, his father, with the children, escaping to France, where he remarried, entrusting the tutelage of his children to their step-mother. She was an easy mistress and the young Audubon was reared in an atmosphere of indulgent plenty. With more foresight than his wife, the boy's father insisted on his education, originally intending him for a maritime or engineering career. The fine arts were not, however, neglected in his education, music and drawing being included in his studies, the latter under the famous French artist, David. His studies, however, did not prevent many rambles into the country, from which he "returned loaded with objects of natural history, birds' nests, birds' eggs, specimens of moss, curious stones, and other objects attractive to his eye." Audubon also began in his early boyhood to draw birds, completing sketches of two hundred specimens.

Finding his son's interest fixed upon other than maritime or military pursuits, the father sent him to America to superintend his estate of Mill Grove on the Perkiomen Creek near Philadelphia, where in Audubon's own words, he found a "blessed spot" and where "hunting, fishing and drawing occupied my every moment, cares I knew not and cared nothing for them." Here, too, he met his future wife, Lucy Bake-well, the daughter of an English gentleman, residing on an adjoining estate.

Before his marriage, Audubon returned for a year to France, where he served for a brief time as a midshipman in the French navy, and where he met a young man named Rosier, who later became his partner in his business ventures in America.

Subsequent to Audubon's return to America the future partners essayed a business apprenticeship in New York, which Audubon signalized by the loss of several hundred pounds in speculation; Rosier similarly losing considerable money. His commercial enterprises, however, did not prevent Audubon from devoting himself to his favorite pursuits, which caused such a disagreeable odor in his rooms that his neighbors demanded, through a constable, an abatement of the nuisance!

Leaving New York, Audubon journeyed to Louisville, where he invested the proceeds of the sale of the Mill Grove prop-

erty in business with Rosier and where he shortly after brought his wife.

Space does not permit us to follow all the wanderings of this brilliant, but eccentric man. His various business adventures were foreordained to failure, and from comfort, if not opulence, he and his ever brave and loyal wife were soon reduced to penury, Audubon earning a meagre penny by giving lessons in drawing, music, fencing and dancing, while his wife acted as governess in a private family.

His roving life in a new and sparsely settled country was full of wild and interesting experiences which are vividly depicted in his journal. His account of an Indian swan hunt in Tennessee gives us a lively picture of the abundance of wild life in America in the early days, and some idea of the cause of its rapid disappearance.

"The second morning after our arrival at Cash Creek, while I was straining my eyes to discover whether it was fairly day dawn or no, I heard a movement in the Indian camp, and discovered that a canoe, with half a dozen squaws and as many hunters, was about leaving for Tennessee. I had heard that there was a large lake opposite to us, where immense flocks of swans resorted every morning, and asking permission to join them, I seated myself on my haunches in the canoe, well provided with ammunition and a bottle of whisky, and in a few minutes the paddles were at work, swiftly propelling us to the opposite shore. I was not much surprised to see the hunters stretch themselves out and go to sleep. On landing, the squaws took charge of the canoe, secured it, and went in search of nuts, while we gentlemen hunters made the best of our way through thick and thin to the lake. Its muddy shores were overgrown with a close growth of cotton trees, too large to be pushed aside, and too thick to pass through except by squeezing yourself at every few steps; and to add to the difficulty, every few rods we came to small nasty lagoons, which one must jump, leap, or swim, and this not without peril of broken limbs or drowning.

"But when the lake burst on our view there were the swans by hundreds, and white as rich cream, either dipping their black bills in the water, or stretching out one leg on its surface, or gently floating alone. According to the Indian mode of hunting, we had divided and approached the lagoon from different sides. The moment our vidette was seen, it seemed as if thousands of large, fat, and heavy swans were startled, and as they made away from him they drew towards the ambush of death; for the trees had hunters behind them, whose touch of the trigger would carry destruction among them. As the first party fired, the game rose and flew within easy

distance of the party on the opposite side, when they again fired, and I saw the water covered with birds floating with their backs downwards, and their heads sunk in the water, and their legs kicking in the air. When the sport was over we counted more than fifty of these beautiful birds, whose skins were intended for the ladies in Europe. There were plenty of geese and ducks, but no one condescended to give them a shoot. A conch was sounded, and after a while the squaws came dragging the canoe, and collecting the dead game, which was taken to the river's edge, fastened to the canoe, and before dusk we were again landed at our camping ground. I had heard of sportsmen in England who walked a whole day, and after firing a pound of powder returned in great glee bringing one partridge; and I could not help wondering what they would think of the spoil we were bearing from Swan Lake."

His picture of the Mississippi in flood is wonderfully impressive.

"I have floated on the Mississippi and Ohio when thus swollen, and have in different places visited the submerged lands of the interior, propelling a light canoe by the aid of a paddle. In this manner I have traversed immense portions of the country overflowed by the waters of these rivers, and particularly whilst floating over the Mississippi bottom lands I have been struck with awe at the sight. Little or no current is met with, unless when the canoe passes over the bed of a bayou. All is silent and melancholy, unless when the mournful bleating of the hemmed-in deer reaches your ear, or the dismal scream of an eagle or a heron is heard, or the foul bird rises, disturbed by your approach, from the carcass on which it was allaying its craving appetite. Bears, cougars, lynxes, and all other quadrupeds that can ascend the trees, are observed crouched among their top branches; hungry in the midst of abundance, although they see floating around them the animals on which they usually prey. They dare not venture to swim to them. Fatigued by the exertions which they have made in reaching dry land, they will there stand the hunter's fire, as if to die by a ball were better than to perish amid the waste of waters. On occasions like this, all these animals are shot by hundreds."

In his journeys Audubon fell in with many interesting characters. One of these was the naturalist Rafinesque. During Audubon's residence in Kentucky, Rafinesque visited him, presenting a letter of introduction in which he was described as an "odd fish" as yet undescribed in published works. Audubon's innocent inquiry as to where the "odd fish" was, led to much amusement and a cordial entente

between the two. "His attire," writes Audubon, "struck me as exceedingly remarkable. A long loose coat of yellow nankeen, much the worse for the many rubs it had got in its time, and stained all over with the juice of plants, hung loosely about him like a sack. A waistcoat of the same, with enormous pockets, and buttoned up to the chin, reached below over a pair of tight pantaloons, the lower parts of which were buttoned down to the ankles. His beard was as long as I have known my own to be during some of my peregrinations, and his lank black hair hung loosely over his shoulders. His forehead was so broad and prominent that any tyro in phrenology would instantly have pronounced it the residence of a mind of strong powers. His words impressed an assurance of rigid truth, and as he directed the conversation to the study of the natural sciences, I listened to him with great delight. He requested to see my drawings, anxious to see the plants I had introduced besides the birds I had drawn. Finding a strange plant among my drawings, he denied its authenticity; but on my assuring him that it grew in the neighborhood, he insisted on going off instantly to see it.

"When I pointed it out the naturalist lost all command over his feelings, and behaved like a maniac in expressing his delight. He plucked the plants one after another, danced, hugged me in his arms, and exultingly told me he had got, not merely a new species, but a new genus.

"He immediately took notes of all the needful particulars of the plant in a note-book, which he carried wrapt in a waterproof covering. After a day's pursuit of natural history studies, the stranger was accommodated with a bed in an attic room. We had all retired to rest; every person I imagined was in deep slumber save myself, when of a sudden I heard a great uproar in the naturalist's room. I got up, reached the place in a few moments, and opened the door; when, to my astonishment, I saw my guest running naked, holding the handle of my favorite violin, the body of which he had battered to pieces against the walls in attempting to kill the bats which had entered by the open window, probably attracted by the insects flying around his candle. I stood amazed, but he



RAFINESQUE

From Popular Science Monthly.

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Chicago.

continued jumping and running round and round, until he was fairly exhausted, when he begged me to procure one of the animals for him, as he felt convinced they belonged to a 'new species.' Although I was convinced of the contrary, I took up the bow of my demolished Cremona, and administering a smart tap to each of the bats as it came up, soon got specimens enough. The war ended, I again bade him good-night, but could not help observing the state of the room. It was strewn with plants, which had been previously arranged with care.

"He saw my regret for the havoc that had been created, but added that he would soon put his plants to rights—after he had secured his new specimens of bats."⁴

Rafinesque was a marked example of the combination of brilliance with eccentricity; his career, filled with striking contrasts of light and shade, forms one of the most pathetic pictures in American science. Born in Constantinople, of Franco-German parentage, traveler, zoölogist, botanist, chemist, geographer, archæologist, historian, philosopher, economist and poet, professor in Transylvania University at Lexington, Kentucky, medalist of the Geographical Society of Paris, associate and correspondent of many of the leading scientists of his day, dying at last in penury, unbefriended and alone in his garret home in Philadelphia; his very corpse seized by his landlord for sale to the dissecting room, rescued by friends and buried in an obscure burial ground, now in the heart of the great city; his course was marked by flashes of brilliance, but ended in obscurity and gloom.

Like many another Rafinesque was ahead of his generation. When he submitted to the Academy of Natural Sciences in Philadelphia a paper describing two genera of fossil jellyfish, it was rejected as unworthy of publication, such a thing as a fossil jellyfish being considered an impossibility in those days. He had clearly in mind the idea of evolution at a time when the doctrine of the fixity of species was firmly entrenched in men's minds. In the title page of his poem on "The World or Instability," published in 1836, he writes:

"If Solomon did say, that nothing new
Under the sun was seen, 'tis not quite true:
Since we contend that every hour and day
Brings novelties, with changes due array.
Whatever had a birth must change sustain,
Unsteady ever be; but not in vain:
Enjoying life must die to live again,
In after lives perfection to attain."

⁴The foregoing quotations are from Audubon's diary in Buchanan's "Life of Audubon."

Living a lonely life, embittered by disappointment, with the memory of a faithless wife behind him, and the ever elusive will-o'-the-wisp of ungratified ambition before him, it is no wonder that his disposition became soured and that he sometimes indulged in caustic criticism of his fellows, winning him their enmity and embittering his own life all the more.

Despite his financial failures Audubon seems never to have lost heart in his ambition to publish his studies and drawings of the birds of America. And in this ambition he was encouraged and materially aided by his ever loyal wife. In the furtherance of this project he visited Philadelphia in 1824, where he met many men prominent in scientific and artistic circles. Among them were Lucien Bonaparte, Le Sueur, the ichthyologist, Murtrie, the conchologist, Sully, the artist and many others. Of his meeting with Titian Peale, the artist-naturalist, he speaks in the following bitter words:

"Showed all my drawings to Titian Peel, who in return refused to let me see a new bird in his possession. This little incident fills me with grief at the narrow spirit of humanity, and makes me wish for the solitude of the woods."⁵

Fighting his way through repeated failure and discouragement, and with the aid of his ever faithful wife, Audubon was finally enabled to reach England and to obtain the funds necessary to the publication of his monumental work, the "Birds of America."

Publication of a book in those days was a different matter from what it is at present. There were no publishers willing to incur the financial risk of printing and illustrating so costly a work as the "Birds of America." For the author then, without independent means, it was necessary to secure enough subscriptions in advance to defray the costs of publication. He, of necessity, became his own book agent. To this end, as well as to supervise the preparation of the elaborate colored engravings illustrating his work, Audubon made several trips abroad, visiting both England and France, where his merit as naturalist and artist gained him ready entrance into the highest circles of art and learning.

Audubon was accompanied on his visit to France by his friend Swainson, one of the prominent ornithologists of the time, and later one of the authors of the "Fauna boreali-Americana," descriptive of the natural history of northern North America, studied by Richardson, naturalist to Sir John Franklin's exploring parties. Swainson's reputation indeed was greater than Audubon's at this time, as he was known in France, where the latter, prior to his visit, had not been heard of.

⁵ *Locus Citatus.*

In the interims between his journeys to England, Audubon was busy in his search for birds and also mammals, visiting among other places, Labrador and Florida, and finally making his last expedition, that up the Missouri River to the mouth of the Yellowstone, primarily to collect material for his "*Quadrupeds of America*," one volume of which was published before his death, and the other two, by his sons, Victor and John, subsequent thereto.

In the early morning of Jan. 27, 1851, in the country home of "Minniesland" on the banks of the Hudson, there passed away the premier of America's early pioneers in science. Today towering apartment houses, and a splendid driveway, look down on "Minniesland," but his work lives after him and his spirit pulses still in the "Audubon Societies" throughout our land.

Both of Audubon's sons followed in their father's footsteps as naturalists and artists, and were early associated with him in his ornithological work, and later in his work on the "*Quadrupeds*," in the course of which the younger of the sons, John, visited both Texas and California, making the journey overland in search of specimens of natural history.

Following the Louisiana Purchase in 1803, both public and private interest awakened in the unknown resources of the vast territory beyond the Missouri and its head waters. An expedition to visit this region, cross the Rockies and descend the Columbia to its mouth was early planned by President Jefferson, under the leadership of his secretary Captain Merriwether Lewis, accompanied by François André Michaux, a French botanist visiting America under the auspices of the French government. Michaux had traveled extensively through eastern North America on botanical explorations, the result of which were his "*Flora boreali-Americana*," and his "*North American Sylva*." Before this plan could be executed, however, he was recalled by his government to France. Nothing daunted by failure Jefferson planned a second expedition, and in 1804-5 Captains Lewis and Clark of the U. S. Army crossed the continent via the Missouri and Columbia Rivers. On this expedition they collected voluminous scientific data dealing in part with the natural history of the region traversed.

It is worth while at this point to glance for a moment at the scientific work of that remarkably versatile man, Thomas Jefferson, a man who in many respects was the prototype of that other statesman-naturalist who has so recently departed from us. Jefferson's interests were very broad. Astronomer, physicist, engineer, anatomist, geologist, zoölogist, botanist, palæontologist, littérateur, educator, lawyer,

farmer, economist and statesman, he indeed was a man of far vision and high achievement, dreamer of dreams and doer of deeds. Writing in the "Magazine of American History" for April, 1885, Mr. Frederic N. Luther says of him:

" . . . In February, 1801, when Congress was vainly trying to untangle the difficulties arising from the tie vote between Jefferson and Burr, when every politician at the capital was busy with schemes and counter-schemes, this man, whose political fate was balanced on a razor's edge, was corresponding with Dr. Wistar in regard to some bones of the mastodon which he had just procured from Shawangunk, Ulster County. Again in 1808, when the excitement over the embargo was highest, when every day brought fresh denunciations of him and his policy, he was carrying on his palæontological studies in the rooms of the White House itself. . . . Never for a moment, however apparently absorbed in other work, did he lose his warm sympathy with nature."

It is amusing to read on the other hand the tribute which his studies called forth from Bryant, then thirteen years old.

"Go, wretch, resign the Presidential chair,
Disclose thy secret measures, foul or fair.
Go, search with curious eyes for horned frogs,
'Mid the wild wastes of Louisianian bogs;
Or, where the Ohio rolls his turbid stream,
Dig for huge bones, thy glory and thy theme."

One of Jefferson's scientific contemporaries was Buffon, the French evolutionist. Buffon had an idea that the animals of the new world are smaller than their near relatives in the old, and that domesticated types are degenerating in the former as compared with the same types in the latter. These contentions were refuted by Jefferson, who exported to Paris specimens of several of our large animals as evidence of his contentions. As a result Buffon wrote to Jefferson, "I should have consulted you, Sir, before publishing my 'Natural History,' and then I should have been sure of my facts."

Jefferson was one of our pioneer plant importers. While minister to Paris he sent to America large numbers of seeds and plants of various sorts. Most of these were failures, among them the olive, the cork oak and the caper. With rice however he was more successful. Noting the great demand for this cereal during Lent in France, and noting further the small importations of American as compared with Italian rice, he set about discovering the reason, and soon ascertained that it was due to the superior quality of the latter grain. In those days importation of plants from one country to

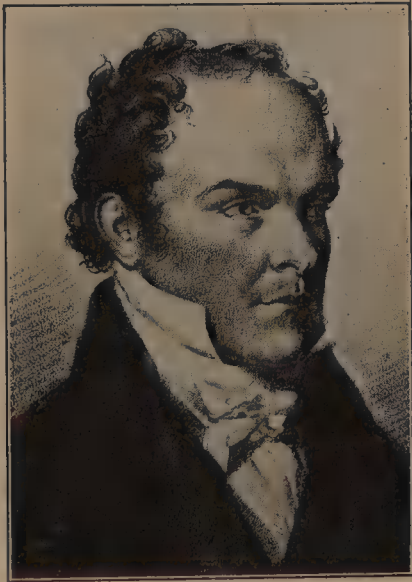
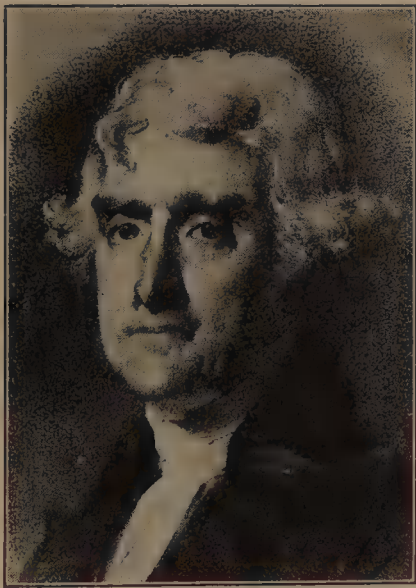
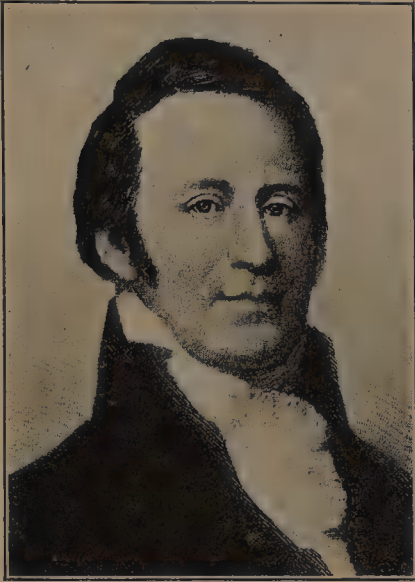
another was difficult, owing to the selfish Jack Horner policy of keeping all the plums at home. Jefferson however visited Italy and carried off successfully some pockets full of rice, which he sent to the Charleston planters, and from which have developed the rice crops of the South today.

Among Jefferson's important contributions to biology were his discovery of the remains of a giant sloth in the mountains of Virginia, which bears his name and which is mentioned elsewhere in this book; his discovery of the bones of the mastodon in Ulster County, N. Y., and his account of the natural history of Virginia, published in his notes on that state.

In 1810 an expedition fitted out by John Jacob Astor set out for the Columbia, which reached the infant village of Astoria near its mouth on February 15, 1812, after suffering untold hardships in the wilderness. On this expedition were two naturalists, both Englishmen; one, John Bradbury sent out by the Botanical Society of Liverpool to collect American plants; and the other, Thomas Nuttall, the ornithologist, and botanist, who was traveling independently. They accompanied it for several hundred miles above St. Louis, but returned before the main party crossed the Rocky Mountains. Later Bradbury visited several of the central western states, the results of all his journeys being interestingly recorded in his "Travels in the Interior of America." Nuttall's travels also took him along the shores of the Great Lakes into Wisconsin, down the Mississippi to St. Louis, up the Arkansas River and finally in company with the naturalist Townsend, across the continent to the Columbia, whence he returned east by the Hawaiian Islands and Cape Horn. On this expedition they traveled with the party of Mr. Nathaniel J. Wyeth of Boston, who in 1833 made a well conceived but ineffectual attempt to recover for the United States the trade lost when, twenty years previously, Astoria passed into the hands of the "Northwest Company," a Canadian company and rival of the "Hudson Bay Company" for the trade of the Northwest.

In 1819-20 Major Stephen H. Long, from whom one of the most inspiring peaks in the Rocky Mountains takes its name, made an expedition under the direction of the War Department to the Rocky Mountains. He was accompanied on this expedition by Thomas Say, the conchologist and entomologist, and Edwin James, a botanist and geologist. Say also accompanied Long on his survey of the Great Lakes region and the valleys of the upper Mississippi and Red River as far as Lake Winnipeg.

The life of the far West in the days when the pioneers blazed their trails for civilization and science through its wildernesses, was one to appeal to the hardy and adventurous. Its virgin



Above, WILLIAM CLARK
Below, THOMAS JEFFERSON

Above, MERRIWETHER LEWIS
Below, THOMAS NUTTALL

Copies supplied by Handy. photo.

wilds too offered a rich reward to the scientific explorer. Its dangers and hardships however presented an effective barrier to all but the most resolute and dauntless. Vivid pictures of this life, with its fascinating beauty and danger, the intense rivalry of the different fur companies, the savage attack and wanton ravage of the lurking Indians, the midnight revel about the roaring camp fire, the games and frolics, feuds and friendships of men without restraint; the challenge of the chase, the elk's whistle and the howling wolf, the magnificence of boundless plain, of towering peak and roaring river, the glory of the sunset and the starlit sky and the terror of the tempest, have been drawn for us by many writers, especially Irving in his "Astoria" and "Captain Bonneville"; and the journals of these early adventurers are as full of enthralling interest as they are of historical and scientific information.

In the early days of American exploration, adventurous eyes were turned to the frozen north, and in the Elizabethan age of English glory her mariners penetrated the frozen seas as far as latitude 72° N., leaving a record of their daring in the names of Frobisher's and Davis' Straits. In the following century, Sir Henry Hudson explored the bay which bears his name, and perished upon its inhospitable waters. A shorter route to India, through the Northwest Passage, was one of the motives of these early voyages. It was on this quest that the famous voyages of Ross and Parry were made, early in the last century.

In 1819-22 Sir John Franklin, who had been second in command of Buchan's polar expedition of the preceding year, undertook the exploration of the Canadian Coast bordering the Arctic Sea. On this expedition he was accompanied by Richardson as surgeon and naturalist, whose name was destined to become famous in the annals of early American biology. The party left York Factory on Hudson Bay on September 9, reaching Cumberland House on October 23, where they wintered. The following year, greatly handicapped by lack of provisions, Franklin and his party pushed northward to Fort Enterprise, where they spent the second winter, and in the summer descended the Coppermine River to the Arctic Sea, whose coast they explored as far as Bathurst Inlet. On the return to Fort Enterprise the party suffered untold hardships, a glimpse of which may be obtained from Franklin's own narrative. The fifth of September, without food or fire, was spent in bed, while a raging storm covered them with several inches of snow. "Our sufferings (writes Franklin) from cold, in a comfortless canvas tent in such weather, with the temperature at 20°, and without fire, will easily be imagined; it was, however, less than that which we felt from

hunger.” Living largely on lichens, they were fortunate enough to kill a musk ox on the tenth. “To skin and cut up the animal was the work of a few minutes. The contents of its stomach were devoured upon the spot; raw intestines which were next attacked, were pronounced by the most delicate amongst us to be excellent.” Finally when Fort Enterprise was reached it was found deserted and provisionless! Here Franklin and his men spent several weeks awaiting succor from Fort Providence, to which a few of the party had pushed on for help; subsisting meantime on lichens, and bits of skin and bones from the refuse heaps of the preceding winter. They were so weak that even when game appeared, none of them were able to go after it. “We saw,” continues Franklin, “a herd of reindeer sporting on the river, about half a mile from the house; they remained there a long time, but none of the party felt themselves strong enough to go after them, nor was there one of us who could have fired a gun without resting it.”⁶ Finally, early in November, relief came from Fort Providence, enabling the party to reach Fort Chipewyan, where they wintered, returning to York Factory the following summer. Such were the surroundings, and such the men, in which, and by whom American biology was made.

Richardson also accompanied Franklin on a subsequent expedition in 1825, together with Drummond, another naturalist, to Great Bear Lake and down the Mackenzie River to its mouth, whence one party under Franklin explored the coast to the westward, while another under Richardson went some nine hundred miles eastward. In 1848-9 Richardson was in charge of one of the expeditions sent in search of Franklin, who never returned from his fateful voyage of 1845. In the course of this search he further explored the coast between the mouths of the Mackenzie and Coppermine Rivers.

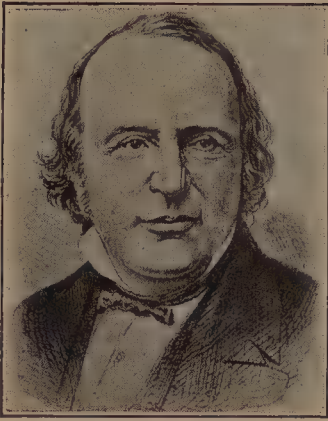
The natural history results of Richardson’s explorations were embodied in his volumes of the “*Fauna boreali-Americana*,” published with the assistance of the ornithologist, Swainson, and the entomologist, Kirby.

Beginning with 1830 and for many years subsequent thereto, different states organized surveys of their natural resources. Of still greater value, however, to natural science were the various government surveys leading up to the Pacific Railroad Surveys and those of the territories, and finally culminating in 1879 in the establishment of the U. S. Geological Survey.

⁶ Quoted from Wright, “The Great White North,” pp. 86-8, by permission of the Macmillan Company.

While these surveys were primarily topographical and geological in purpose, they were usually accompanied by naturalists, whose duty it was to investigate and report upon the wild life, both plant and animal, of the region visited, and to them much of our knowledge of the natural history of the United States is due.

Of prime importance in the work of these naturalists were the discoveries of the palæontologists. The western plains and mountains constitute a veritable storehouse of buried treasure, and the pick and shovel of the palæontologist uncovered here a large part of the material for writing the history of ancient life.



LOUIS AGASSIZ

From Popular Science Monthly.

*Copy furnished by Conrad
Lantern Slide Company,
Chicago.*

These were days too when it was not impossible for one man to cover an extensive field of science. Thus we find the elder Agassiz equally famed as a geologist and zoölogist, and Dana, the noted geologist, professor at Yale from 1850 to 1890, writing a monumental work on the Zoöphytes and Crustacea of the Wilkes Exploring Expedition; Cope, master not only of vertebrate palæontology but of modern fishes, amphibia and reptiles as well, and Leidy, botanist, mineralogist, geologist, palæontologist, parasitologist, protozoölogist and comparative anatomist.

A notable event in American science was the advent of Louis Agassiz in 1846. Born in 1807 at the little town of Motiers in Switzerland, the son of a clergyman, he early displayed that love of natural history, which made him famous. Champion fencer and jolly comrade, as well as gifted student, his university days at Zurich, Heidelberg and Munich found him a leader among his fellows and his room in Munich dubbed by them "The Little Academy." His scientific work early attracted the attention of Humboldt and Cuvier, who gave him all possible assistance in his career. While professor of natural history in the University of Neuchâtel, Agassiz gained world wide fame by his studies in zoölogy, palæontology, and especially on the glaciers of the Alps. In 1846 he came to America, where he remained until his death in 1873. During most of this time he was professor of natural history at Harvard, where he gathered about him a group of men and

sent them forth to become leaders of biology in America. Indeed, it was as teacher, rather than as investigator, that Agassiz's influence was most widely felt. Possessed of a compelling personality, remarkable diction and inspiring enthusiasm, he left an impress upon biology in this country that can never be effaced. He was the founder of the Museum of Comparative Zoölogy of Harvard University, while his summer school at Penikese in 1873 was the forerunner of biological stations in America. A disciple of Cuvier, he was ever an ardent champion of his views and an opponent, albeit a warm personal friend of Darwin.

Pupil of Agassiz at Neuchâtel, and later his co-worker in America, was Girard, who prepared the report on the reptiles of the Wilkes expedition. Girard was better known, however, for his work on fishes, in the course of which he studied much of the material collected by the U. S. Surveys.

While exploring naturalists were busy gathering the unknown fruits of our virgin fields and forests, their colleagues in the dim and dusty rooms of museum and college were no less busy in making known the results of their harvests. Dr. Joseph Leidy, a Philadelphia physician, professor of anatomy at the University of Pennsylvania and later professor of natural history at Swarthmore College, was one of the most noted of these early college and museum men. He is a striking example of the "all around" naturalist of the early days, his writings embracing a wealth of subjects of both extinct and living animals, and ranging from the unicellular animals to man. Of his notable works one of the earliest was his account of the fossils from the "bad lands" of Nebraska, collected by one of the surveys of the then (1850) Northwest Territory, conducted by the geologist, David Day Owen, under the direction of the U. S. Treasury Department.

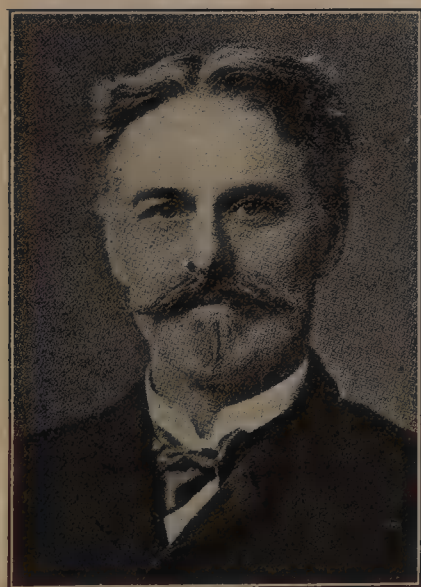
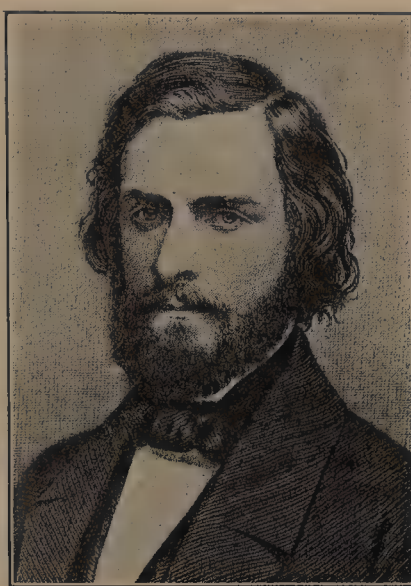
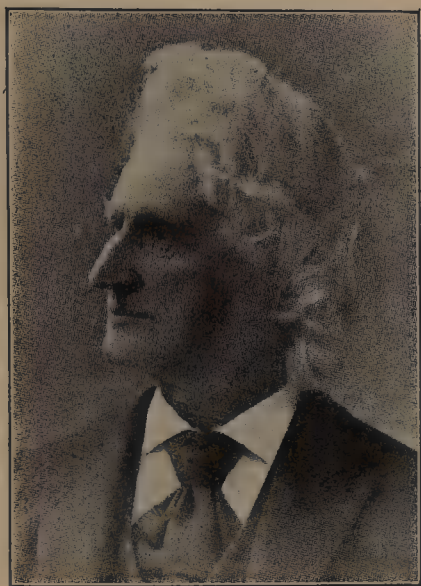
Colleagues of Leidy in the study of the fossils brought back from the West by the government surveys, and by exploring parties sent out by museums and colleges, were two men whose names stand in the front rank of our palæontologists—Othniel Charles Marsh and Edward Drinker Cope.

As professor of palæontology at Yale, Marsh inaugurated in 1870 a series of scientific expeditions into the Western States, the results of which were the splendid collections of vertebrate fossils of Yale and the U. S. National Museum, and the stores of information about the pre-historic life of our continent which Marsh gave to the world and which soon made him famous. His earlier expeditions were undertaken and largely supported by himself, but after the organization of the U. S. Geological Survey in 1879, he became connected with it

as palæontologist and thereafter worked under its auspices. His expeditions took him into the western plains country and the Rocky Mountains, where he discovered the remarkable birds with teeth, *Hesperornis* and *Ichthyornis*, and a host of dinosaurs, the lizard-like reptiles, many of them giants of the animal world, whose bones have been unearthed in such numbers on our western plains, and are now reposing in so many museums both here and abroad, and whose biographies fill so many ponderous volumes on the shelves of our libraries. Here too he collected a series of skeletons of fossil horses which has furnished one of the strongest evidences for evolution known, and which served to recast the views regarding the descent of the horse which were current at that time. In 1876 when Huxley visited America, he spent a week with Marsh inspecting his collections of fossils at Yale. Huxley was at this time preparing to deliver a lecture in New York on the evolution of the horse, and as a result of his study of the Yale collections this lecture was largely rewritten. When Marsh had brought out box after box of specimens to illustrate various points in their discussion, Huxley finally turned to him and said, "I believe you are a magician; whatever I want, you conjure it up."

As a further result of this conference Huxley predicted the discovery of the then unknown five-toed ancestor of the horse, and sure enough, less than two months later Professor Marsh "dug up" the renowned *Eohippus* in the Eocene strata of the West.

Cope, one of the most indefatigable, brilliant and versatile of American biologists, was born and died in Philadelphia. When a young man he served as professor of natural science in Haverford College, later becoming connected with the government surveys of the territories under Wheeler and Hayden. For several years he was curator of the Academy of Natural Sciences of Philadelphia, and finally professor of geology in the University of Pennsylvania. In the literature of modern fishes, and especially of reptiles and amphibians, Cope's work will ever be classic, but it was chiefly in the field of vertebrate palæontology that he became famous. As a member of government surveys and the Philadelphia Academy his work on the fossil vertebrates of the West was both able and voluminous, and contributed largely not alone to his own fame, but to that of the institutions which he represented. As illustrative of American idealism, a trait for which our people have not hitherto received due credit, it is both pleasant and stimulating to think of Cope on his deathbed putting the finishing touches on his report upon



*Above, JAMES DWIGHT DANA
Below, EDWARD DRINKER COPE*

*Above, JOSEPH LEIDY
Below, OTHNIEL CHARLES MARSH*

Courtesy of Dr. Geo. P. Merrill.

Here too we meet with Sir Joseph Hooker, director of the Kew Gardens, England, Darwin's elder brother in science, and the man who, with Lyell, the geologist, was more than any other responsible for the publication of the "Origin of Species."

In the introduction to his scholarly and at the same time interesting work "A History of Land Mammals in the Western Hemisphere," Professor Scott tells us that "One afternoon in June, 1876, three Princeton undergraduates were lying under the trees on the canal bank, making a languid pretence of preparing for an examination. Suddenly, one of the trio remarked: 'I have been reading an old magazine article which describes a fossil-collecting expedition in the West; why can't we get up something of the kind?' The others replied, as with one voice, 'We can; let's do it.' This seemingly idle talk was, for Osborn and myself, a momentous one, for it completely changed the careers which, as we then believed, had been mapped out for us. The random suggestion led directly to the first of the Princeton palæontological expeditions, that of 1877, which took us to the "Bad Lands" of the Bridger region in southwestern Wyoming."⁹ In this trivial incident lay the germ of the collections of vertebrate fossils of Princeton University, and the American Museum of Natural History, and led to many of the most important palæontological discoveries in the world.

Next to Audubon, Agassiz and Gray, no name is more prominent in the early annals of American biology than that of Spencer Fullerton Baird. In his early career Baird was professor of the natural sciences in Dickinson College, becoming assistant secretary of the Smithsonian Institution in 1850. While in this position he founded the National Museum and prepared the monumental reports upon the mammals and birds collected by the several Pacific Railroad surveys during the decade of the fifties. On the latter reports he was assisted by the well-known ornithologists, John Cassin (of Philadelphia) and Geo. N. Lawrence (of New York). He was also joint author with Brewer and Ridgway of the splendid "History of American Birds," published from 1874 to 1884.

Baird was the Nestor of economic zoölogy in America. Through his activity, aided by other scientists and fish culturists throughout the United States, the U. S. Fish Commission was established in 1874, and he was appointed its commissioner, a post which he filled without salary for a number of years. The organization of this great institution, whose work is briefly mentioned in another chapter, we owe to Professor Baird.

⁹ Quoted by permission of the Macmillan Company.

A hundred years ago the scientific thought of America was as firmly rooted in the belief in the fixity of species as was that of Europe. American colleges were almost, if not entirely, presided over by doctors of divinity, and there was even a feeling in many quarters against the sciences, especially of geology, as tending to unsettle the belief of the young in the Mosaic account of creation; and yet, even so early as 1833 there appears to have been an underlying current of unrest present in the minds of some, for in the second American edition of "Bakewell's Geology," published in this year, under the editorship of Silliman, the lawyer, chemist and geologist, who was professor of chemistry and natural science at Yale, we read "Any attempt to disprove the truth or genuineness of the Pentateuch, and Genesis in particular, is wholly superfluous, and quite aside from any question that can in this age be at issue between geologists. No geologist at the present day erects any system upon the basis of the scripture history." The editor however accepted the Mosaic account as true and endeavored to bring it into accordance with the geological record. In the first edition of the same work published four years earlier, Silliman considered the discoveries of geology as consistent with the biblical

story, stating that "respecting the deluge, there can be but one opinion . . . geology fully confirms the scripture history of that event."¹⁰ Archaic as these views appear today, they show none the less the leaven that was beginning, slowly, yet none the less surely, to work in men's minds, preparing them for the acceptance of the gospel of truth. The anti-Darwinian attitude in America was supported largely by the influence of Louis Agassiz, who, in spite of his personal friendship for Darwin, was ever his bitter opponent in the arena of science. But Darwin found an equally powerful champion in Asa Gray, the botanist, and colleague of Agassiz on the Harvard College faculty. Darwin had met Gray on a visit of the latter to England, some years before the publication of the "Origin of Species," and in its preparation he frequently consulted



SPENCER FULLERTON BAIRD
First U. S. Fish Commissioner.
*Courtesy of the U. S. Bureau
of Fisheries.*

¹⁰ Merrill, "Contributions to the History of American Geology," in Rep. U. S. N. M., 1904, pp. 292 and 317.

him. Gray, on his part, staunchly supported Darwin in the bitter attack which was launched against him after the appearance of his work, although he was unable, on account of his religious views, to accept it in its entirety. His opinion of Darwin's work is evidenced in a letter to Hooker written in 1860. "It is done in a masterly manner. It might well have taken twenty years to produce it. It is crammed full of most interesting matter . . . and . . . makes out a better case than I had supposed possible. . . . Tell Darwin all this. . . . As I have promised, he and you shall have fair play here."¹¹

In science, as in every other field of human endeavor, it is the individual who counts most in progress. Nevertheless the individual works most effectively in co-operation with his fellows. And so in the development of American science organization has been a powerful factor.

About 1840 there was organized the Society of American Naturalists and Geologists, which in 1848 was expanded into the American Association for the Advancement of Science, which has a present membership of over 12,000, divided into twelve sections and having twenty-six societies affiliated with it, several of which are organized in biology. The annual convocation of this Association and its affiliated societies during Christmas week serves as a "get-together" meeting, and is a splendid stimulus to scientific work.

Fragmentary as is the foregoing account of the rise of biology in America, it nevertheless shows us something of the men who were pioneers in this great field, their endeavors and achievements, their friendships and their petty jealousies; it gives us a glimpse of the major trends of biological research and may serve perchance as a background for the later history of biology, its institutions, its discoveries and theories, which is to follow.

¹¹ Darwin's "Life and Letters," p. 238. D. Appleton and Company.

CHAPTER II

Biological institutions in America. Universities and colleges, museums, botanical and zoölogical gardens, biological stations and endowed laboratories.

Biology's service to the world has been rendered under many auspices, chief of which has been the college and the university. Harvard College was the first of these to be established in America. No sooner were the early colonists of Massachusetts Bay domiciled in the wilderness than they began to think of education, not only for their own sons, but also for those of their savage neighbors, hoping doubtless to convert them to civilization as readily as they turned the forest into fertile fields of grain.

Amidst the struggle for existence with savage men and barren nature, in the face of privation, hardship, danger and death; while "the sounding aisles of the dim woods rang" not alone to "the anthem of the free" but also to the war-whoop of the Indian, and the gleam of burning thatch lit up "the depths of the desert gloom;" the pilgrim fathers forgot not posterity while thinking of themselves, and in the midst of the wilderness established institutions of freedom, religion and learning.

"About midnight we heard a great and hideous cry, and our Sentinell called, Arme, Arme! So we bestirred our selues and shot off a couple of Muskets, and noyse ceased; we concluded, that it was a company of Wolues or Foxes, for one told vs, hee had heard such a noise in New-found-land. About fife a clocke in the morning wee began to be stirring, and two or three which doubted whether their Peeces would goe off or no, made tryall of them, and shot them off, but though at nothing at all.

"After Prayer we prepared our selues for brek-fast, and for a journey, and it being now the twilight in the morning, it was thought meet to carry the things downe to the Shallop: some sayd, it was not best to carry the Armour downe, others sayd, they would be readier; two or three sayd, they would not carry theirs, till they went themselues, but mistrusting nothing at all: as it fell out, the water not being high enough, they layd the things downe vpon the shore, & came vp to brek-

fast. Anone, all vpon a sudden, we heard a great & strange cry, which we knew to be the same voyces, though they varied their notes. One of our company being abroad came running in, and cryed They ar men, Indians, Indians; and withall, their arrows came flying amongst vs, our men ran out with all speed to recover their armes, as by the good Providence of God they did. In the meane time, Captaine Miles Standish, having a snaphance ready, made a shot, and after him another; after they two had shot, other of vs were ready, but he wisht vs not to shoot, till we could take ayme, for we knew not what need we should haue, & there were foure only of vs, which had their armes there redie, and stood before the open side of our Baricado, which was first assaulted; they thought it best to defend it, least the enemie should take it and our stuffe, and so haue the more vantage against vs; our care was no lesse for the Shallop, but we hoped all the rest would defend it; we called vnto them to know how it was with them, and they answered, Well, Well, every one, and be of good courage: we heard three of their Peeeces goe off, and the rest called for a fire-brand to light their matches; one tooke a log out of the fire on his shoulder and went and carried it vnto them, which was thought did not a little discourage our enemies. The cry of our enemies was dreadfull, especially, when our men ran out to recover their Armes, their note was after this manner, Woath woach ha ha hach woach: our men were no sooner come to their Armes, but the enemy were ready to assault them.

“There was a lustie man and no whit lesse valiant, who was thought to bee their Captaine, stood behind a tree within halfe a musket shot of vs, and there let his arrowes fly at vs; he was seene to shoote three arrowes, which were all avoyded, for he at whom the first arrow was ayimed, saw it, and stooped downe and it flew over him, the rest were avoyded also: he stood three shots of a Musket, at length one tooke as he sayd full ayme at him, after which he gaue an extraordinary cry and away they went all; wee followed them about a quarter of a mile, but wee left sixe to keep our Shallop, for we were carefull of our businesse: then wee shouted all together two severall times, and shot off a couple of muskets and so returned: this wee did that they might see wee were not afrayd of them nor discouraged.

“Thus it pleased God to vanquish our Enemies and giue vs deliverance.”¹

(January 23, 1697)

“I attempted, this Day, the Exercises of a secret Fast before the Lord. But so extremely cold was the weather, that in a

¹“Journal of the Pilgrims of Plymouth,” 1620, pp. 44-46.

ward Room, on a great Fire, the Juices forced out at the End of short Billets of Wood, by the Heat of the Flame, on which they were laid, yett froze into Ice, at their coming out. This Extremity of the Cold caused mee to desist from the purpose, which I was upon; because I saw it impossible to serve the Lord, without such Distraction as was inconvenient.

(January 11, 1719-20)

"Tis dreadful cold. My Ink-glass in my Standish is froze & splitt, in my very stove. My Ink in my very pen suffers a congelation: but my witt much more." . . .

"Sabbath, Jan. 24, 1686, Friday night and Satterday were extream cold, so that the Harbour frozen up, and to the Castle. This day so cold that the Sacramental Bread is frozen pretty hard, and rattled sadly as broken into the plates.—Samuel Sewall.

"Lord's Day, Jan. 15, 1715-6. An Extraordinary Cold Storm of Wind and Snow. Blows much worse as coming home at Noon, and so holds on. Bread was frozen at the Lord's Table. . . . Though twas so Cold, yet John Tuckerman was baptised. At six a-clock my ink freezes so that I can hardly write by a good fire in my Wive's Chamber. Yet was very comfortable at Meeting. Laus Deo.—Samuel Sewall." ²

Such was the cradle of higher education in America.

In 1636 the Colony Court "agreed to give £400 towards a schoole or collidge," which in 1637 was located at Cambridge and later received its name from its first patron, the Rev. John Harvard, who died in Charlestown in 1638, leaving one half of his estate (about £800) and his library to the infant college. The first of the buildings erected was known as "The Indian Collidge" with rooms for twenty youthful savages, several of whom attended, but only one of whom graduated from it. History repeats itself in the case of many of the "youthful savages" within its walls today. Here the first college text-books were printed, including the Apostle Eliot's translation of the Bible into the Indian language, primers, grammars, tracts, etc. It is possible that the missionary spirit of the founders of the college was not a wholly disinterested one, since many of its funds were obtained abroad for the express purpose of converting the heathen; or in more materialistic terms, making a bad Christian out of a good savage.

Harvard College was followed by William and Mary's College (1692), Yale (1700), Princeton (1746), the University

¹ Hanscom, "The Heart of the Puritan," pp. 29-30, 210. By permission of the Macmillan Company.

of Pennsylvania (1749), and King's College (now Columbia University) in 1754. These early colleges and their successors, prior to the early part of the last century, were supported mainly by private funds, given largely in the form of endowments; but since 1837, when the University of Michigan was founded, most of the states maintain universities at public expense. The private institutions have been almost exclusively supported by religious societies, even some of the great universities, which today are non-sectarian, such as Harvard, Yale and Princeton, having been originally established on a religious basis.

The early instruction in our colleges and universities was strictly classical. The appointment of Benjamin Silliman as professor of chemistry and natural science at Yale in 1802, therefore marks an epoch in the history of American education. It is interesting to note that the young professor, at the time of his appointment but twenty-three years of age, was a lawyer by profession, with no knowledge whatever of the sciences he was to teach. He says of his appointment that it "was of course the cause of wonder to all, and of cavil to political enemies of the college. Although I persevered in my legal studies . . . I soon after the confidential communication of President Dwight (informing him of his probable appointment) obtained a few books on chemistry and kept them secluded in my secretary, occasionally reading in them privately. This reading did not profit me much. Some general principles were intelligible, but it became at once obvious to me that to see and perform experiments and to become familiar with many substances was indispensable to any progress in chemistry, and of course I must resort to Philadelphia, which presented more advantage to science than any other place in our country."³

As Yale was the pioneer in breaking away from "the traditions of the elders," and establishing a professorship in science, so too was it the pioneer in establishing soon afterward (1824) a distinct organization or school, the Sheffield Scientific School, for scientific instruction. In 1847 a similar organization (the Lawrence Scientific School) was established at Harvard, and soon the teaching of science in American colleges and universities was placed on an equal footing with that of art and letters. At the present time indeed science, tried alike in the fires of war and the sunshine of peace, stands preëminent, both in education and in industry.

Biology in American schools owes its birth primarily to Agassiz and Gray, colleagues on the Harvard faculty at the

³ Merrill, "Contributions to the History of American Geology," after G. P. Fisher, "Life of B. Silliman," p. 215.

middle of the last century. After the impelling influence of these two great teachers, it has made a lusty growth. In early days the college professor was supposed to be as many sided as the country "school marm" of the present day and generation. No man was sufficiently well educated to occupy a professor's chair unless he was an authority in at least two major sciences, while the idea of a professor confining his attention to a single branch of one of these sciences was unheard of. Today all our great universities have two entirely separate departments of biology (botany and zoölogy) each with a staff of from five to ten or more members, each one of whom has in charge his own particular branch of the subject. To appreciate the multiplicity of modern science one need but turn to any recent program of a scientific society where the papers are arranged by subjects. Thus at the 1921 meeting of the American Society of Zoölogists there were papers presented in the following branches of zoölogy: embryology, cytology, parasitology, evolution, genetics, ecology, distribution, general physiology, and comparative anatomy. The average college catalog contains such a "feast of fat things" as to impair the digestion of even the most voracious of student "sharks."

But with the passing of the "good old days" when every college "prof" was supposed to be a "walking encyclopedia" has come a far more exacting age for teacher and investigator alike, for modern standards of success demand of both a far more encyclopedic knowledge of science, than was expected of their forbears. The inter-relations of the many branches of science, and their intimate dependence one upon the other, demands a much more extensive, and withal exact knowledge of their subject on the part of biologists today, than was needed in the past. Especially is this true in the field of experimental biology, which has made such remarkable strides in the last two decades, and which employs as its handmaidens its sister sciences of chemistry and physics. Today indeed chemistry and biology are united in the new science of biochemistry, one which, for possibility of discovery of the most elusive secrets of nature, gives more promise than any other field of scientific quest and conquest.

With this ever increasing specialization and complexity of biology (and the same is no less true of other sciences) have come ever increasing demands for equipment on the means of our higher institutions of learning. Time was when the biological laboratory was considered equipped if it possessed a few old microscopes, hand lenses and dissecting instruments, a little glassware, a few chemicals and some pickled caricatures of things which were once alive. Today the work shop and

class room of the well equipped biologist contains not only the most modern microscopes (the instrument par excellence of biological research) but microtomes for cutting sections of microscopic material down to a twenty-five thousandth of an inch in thickness; electrically controlled incubators, where cultures of microscopic organisms and growing tissues can be held within one degree F. of any desired temperature; electrically driven centrifuges running at speeds of from three to four thousand revolutions per minute; projection apparatus for projecting pictures, microscopic preparations, and even living animals themselves upon the demonstration screen, or drawing board; apparatus for taking photographs of these preparations at magnifications of from one to two thousand diameters; delicate balances for weighing down to a twenty-five thousandth of an ounce or less, and hot houses and aquaria where living material for study may be always available.

Such is some of the more common apparatus of the biological laboratory. In laboratories devoted exclusively or primarily to research, such as those at Woods Hole, Cold Spring Harbor and elsewhere, reference to which will be made below, apparatus of a special, and often costly type is usually found in addition to the more common equipment outlined above.

The biological laboratory of college or university is not however a separate institution especially devoted to biology, but merely a part of a larger institution dedicated to the dissemination and advance of all knowledge. Yet it is through this channel that the greatest contributions to biology have thus far come. In considering biological institutions however we are primarily interested in those devoted exclusively to this science, including our museums, government and endowed laboratories, and others of similar character.

The early history of biology in America was as we have seen closely associated with the museums. From their members in many instances went forth the collectors who accompanied the early explorers into virgin forests, across trackless prairies and through the wild defiles of mountain fastnesses. And it was to the museums that these collectors returned to study and describe the treasures which they had found.

Numerous as are the splendid natural history museums in America, space limits us to a brief consideration of but three, as typical of the achievements of American science in this field. Of our larger museums, especially those devoted primarily to natural history, the earliest established was the Academy of Natural Sciences in Philadelphia. The dawn of the year 1812 was darkened by the cloud of war which hung low over America. The one amusement house in Philadelphia,

the old Walnut Street Theatre, was seldom open, and the city's youth were wont to gather in tavern and oyster house to discuss the momentous events of the times. Under circumstances such as these a few young men who were interested in natural history met at the home of one of their number on January 25, 1812, for the organization of a society whose purpose, according to the minutes of the meeting, should be "the rational disposition of otherwise leisure moments." Their collections at this time comprised "a few insects, corals and



THE ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA, 1912
From the Academy "Proceedings."

shells, a dried toad fish, and a stuffed monkey." From this primitive beginning has come the great institution which has contributed, perhaps more than any other factor, to making Philadelphia one of the homes, as it was the birthplace of American biology. In the early years of the last century Philadelphia was the Mecca of American biologists. From here Alexander Wilson started on his ornithological travels. Hither came Audubon, seeking support for the "Birds of America," and through the generosity of Edward Harris, a Philadelphian, he was enabled to make his journey up the Missouri River. Lucien Bonaparte, who continued the work of Wilson, after the latter's death, was for a time resident at

Philadelphia. The early naturalist explorers, Say, Nuttall and Townsend, were associated with the Academy at Philadelphia, two of whose members accompanied the famous Wilkes Expedition to the Antarctic. The Academy was associated also with the early Arctic expeditions under Kane and Hayes, while Peary's Greenland expedition of 1891 was conducted under its auspices. Many are the names famous in the annals of American biology which have been associated with the Academy of Natural Sciences, Leidy, Cope, Cassin, Bachman, Le Sueur, Gill, Osborn and a host of others.

The collections of the Academy, descendants of the stuffed monkey and the dried toad of its founders, have grown to occupy the first rank among biological exhibits in America. While they are surpassed in size and display by those of the American Museum of Natural History and the U. S. National



THE AMERICAN MUSEUM OF NATURAL HISTORY IN NEW YORK
Courtesy of the Museum.

Museum, for reference purposes along certain lines they are second to none in the world. Its library too is one of the best in America in biology, especially in the works of the early writers. Pioneer among American museums the Academy of Natural Sciences of Philadelphia has blazed many a trail for biologists into the unknown.

It would indeed be difficult to assign a premier place to any one museum of natural history in America, but were one to undertake such a thankless task, his choice would be likely to fall on the American Museum of Natural History in New York City, which in breadth of purpose, in the extent and value of its collections, and in its scientific achievements is second to none in this country. Founded in 1869 it now occupies a \$4,000,000 structure in Central Park, which was built and is maintained by the city, while the expense of the collections and investigations is provided for by an endowment, by dues of members and by private contributions.

Truly may it be said of the American Museum that its "lines have gone forth throughout all the earth, and its (men) to the ends of the world." From frigid pole and torrid equator, from rain-soaked forest and from sun-baked desert, from Andean height and Amazonian jungle have come the treasures, which constitute today one of the finest exhibits of natural history in the world. To attempt any adequate account of the Museum and its work in this place would be out of the question, but brief mention may be made of a few of its more important features.

The progress of American palæontology, outlined in another chapter is largely due to the Museum, and its splendid col-



THE BLUE SHARK WITH SCHOOL OF YOUNG

Photograph of a group in the American Museum of Natural History in New York.

Courtesy of the Museum.

lection of fossil vertebrates bears witness to the story of the past, which its investigations have revealed.

Until comparatively recent years we have been accustomed in our museums to display case after case and row upon row of more or less indifferently stuffed specimens, with jar after jar of "pickled" snakes and turtles and case upon case of pinned butterflies and moths. But no hint was there of the activities and home of the living thing. Today our best museums, largely under the inspiration of the American Museum, are exhibiting groups of birds and mammals, reptiles, fish and other forms, illustrating their homes and lives in Nature's setting. Here one finds for example the duck hawks, with their nest and young perched among the rocks



THE HOME OF THE DUCK HAWK IN THE HUDSON PALISADES
 Photograph of a group in the American Museum of Natural History
 in New York.

Courtesy of the Museum.



A FLORIDA SWAMP

Photograph of a reptile group in the American Museum of Natural
 History in New York.

Courtesy of the Museum.

of the Palisades, with their great walls painted in the background and the lovely Hudson flowing at their base. There is the reedy border of a lake from central Oregon filled with the wild fowl and their nests. Another exhibit shows a bit of a Florida cypress swamp, with alligators of various ages and the mother guarding the nest in which the young are hatching from the eggs. Here too are shown many species of snakes, and amphibians, all modeled in wax and colored from living specimens. Yet another group illustrates the blue shark with a school of young among the sargassum weed of the Gulf Stream, while still another displays an oak tree in leaf with its branches covered by hosts of the beautiful monarch butterfly as it appears when migrating.

A unique feature in the Museum's exhibit is Darwin Hall



THE GAME OF THE "MEN OF THE OLD STONE AGE"

The woolly rhinoceros, with the saiga antelope and mammoth in the distance.

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wherein are displayed groups of invertebrate animals illustrating the evolution of this portion of the animal kingdom from the Protozoa to the ascidians. Among the former are models of disease producing types such as the organisms causing malaria and the deadly African sleeping sickness. Here too are wax and glass models of the Malaria mosquito, reproducing with wonderful delicacy even such minute parts as the bristles on its body. The work of man in molding the form of animals to his will is illustrated by cases of pigeons and other domestic animals, while the results of modern research in heredity are shown among other ways in the offspring of a pair of rats, and in a demonstration of the inheritance of color in the four o'clock.

In the Hall of the Age of Man is depicted by painting and model the story of the "Men of the Old Stone Age" as they lived in their cavern homes and hunted with implements of



MONARCH BUTTERFLIES

Photograph of a group in the American Museum of Natural History
in New York.

Courtesy of the Museum.

flint the woolly rhinoceros, the mammoth, mastodon and royal bison, which roamed the world when the glaciers held much of the northern hemisphere within their grasp.

But the mere exhibition of nature's wonders is by no means the only, or even the primary function of the American Museum. The discovery of her workings and her secrets is fundamental to their demonstration in its halls. And so with the gathering of material for its exhibits has gone hand in hand the gathering and publication of information relative thereto, much of which is rehearsed in other chapters of this book. The spread of knowledge through research, publication and exhibition is the comprehensive function of every museum. As further illustration of this function is the work of the public health department of the Museum, whose purpose can best be stated in the words of its curator. Its plan is to "present a fairly comprehensive picture of the life of man as an animal, his place in the general scheme of natural history, his relations to his geographical and meteorological surroundings, the parasites which cause his diseases, and the animals and plants which serve him for food and clothing. The plan . . . giving a survey of the cycle of human life, its dangers and its safeguards, complete enough to satisfy the curiosity of the ordinary man and to teach him what he needs to know in order to keep sound and well, is an extensive one. . . ." In partial fulfilment of this plan the department has installed exhibits of the disposal of sewage and garbage, the water supply of cities, its relation to rainfall and the ways of safeguarding it from pollution; the composition of water and the microscopic organisms which it contains. Some of the exhibits in this department are a series of models of different sorts of bacteria, models of insect carriers of disease, the flea, louse, yellow fever mosquito and the house-fly. The mosquito exhibit shows among other things the condition of the French hospitals in Panama, as compared with those installed by the Americans, the life history of mosquitoes and methods of combating them by oiling, drainage, fumigation, etc. The department also maintains a growing collection of living bacteria including hundreds of different varieties, from which were sent out in 1918 over 3,000 cultures free of charge to laboratories throughout the country.

During the Great War the Museum aided in the food conservation movement by the preparation of a food exhibit illustrating the character of food, its use in human metabolism, the adjustment of the daily ration to meet the increasing cost of living, and showing some new and as yet little used sources of food, such as seaweeds, snails, mussels, cuttle fish, etc.

Such in brief are a few of the activities of this splendid institution.

One of the best additions to the architecture of the new Washington is the building of the National Museum located on the "Mall" or park, which stretches westward from the Capitol to the Potomac River. The building is a simple, but imposing structure of white granite and so arranged as to provide the greatest amount of floor space possible in the



NEW SOURCES OF AQUATIC FOOD, KELP, SNAILS, MUSSELS AND SQUID

Photograph of a group in the American Museum of Natural History in New York.

Courtesy of the Museum.

area covered. Here are housed the natural history and anthropological collections of the U. S. Government, whose formation was begun by the Wilkes exploring expedition around the world in 1838-1842.

In 1846 the Smithsonian Institution was established by act of Congress in accordance with the will of the English mineralogist James Smithson, who left an estate of about a half million dollars to the United States for the "increase and diffusion of knowledge among men." This act made the National Museum a part of the Smithsonian Institution. The early collections of the government were augmented partly

through the personal efforts of Professor Baird, the then assistant secretary of the Institution, and partly through the efforts of the scientists who accompanied the government surveys sent out about the middle of the last century. Professor Baird awakened the interest of officers of the army and navy, fishermen, fur traders, private explorers and members of the Hudson's Bay and Western Union Telegraph Companies in the collection of natural history objects, and in this way a large amount of valuable material was secured by the Institution. Since its establishment the National Museum



THE U. S. NATIONAL MUSEUM

One of the architectural features of the new Washington.

Courtesy of the Museum.

has become the regular repository of the splendid collections made by the U. S. Biological Survey, the Bureau of Fisheries, the Bureaus of Animal and Plant Industry, and the U. S. Geological Survey. Much material has also been gathered through the expeditions of the Smithsonian Institution itself.

The ethnological exhibits of the Museum are perhaps its finest productions, but it has many beautiful groups of birds and mammals as well, and a splendid collection of fossils.

Its research work and resultant publications are largely technical, consisting of the monographing and description of groups and species of animals and plants in its collections.

One of its important educational features is the distribution

of duplicate sets of specimens to schools and colleges throughout the country. It also fills an important place as a convention center, not only for the scientific societies of Washington, but for national and international gatherings as well.

Another group of biological institutions are the zoölogical and botanical gardens and aquaria, upon the possession of one or more of which nearly every city of any size in America prides itself.

Established primarily for purposes of display, some of these institutions have performed a much more important service in adding to our knowledge of the animals and plants which they contain. A brief account of a few of them will serve to illustrate their place in American biology.

A leader in this, as in other lines of science, Philadelphia established a zoölogical garden as early as 1859. Along the banks of the Schuylkill River in Fairmount Park are housed the extensive collections of the Zoölogical Society, which are supported in part by the city, in part by memberships and partly by paid admissions to the garden. The grounds of the Society and its financial means are too small to admit of either the best enclosures for its animals or their proper scientific study. It furnishes considerable material however to the Academy of Natural Sciences of Philadelphia, and maintains a pathological laboratory for the study of diseases infecting its stock.

In 1807 the United States built a fort called the Southwest Battery, and later Castle Clinton, on the lower end of Manhattan Island, from which this section of New York has derived its name of "the Battery." In 1823 it was given to the city for an amusement hall known as Castle Garden, which welcomed several presidents and other distinguished visitors, including the Hungarian patriot, Kossuth; and its walls frequently echoed the wonderful notes of Jenny Lind. From 1855 to 1890 over 7,500,000 immigrants passed through its doors. In 1896 it became a public aquarium, passing in 1902 under the control of the New York Zoölogical Society, which was chartered in 1895. While the housing and equipment of the aquarium are wholly inadequate, it nevertheless maintains one of the largest and best aquaria of both salt and fresh water fishes in the world.

The Zoölogical Society maintains gardens in Bronx Park, in New York, which have in a few years joined the ranks of the leading zoölogical gardens of the world, and share with the National Zoölogical Park in Washington the first place for institutions of this kind in America.

The old style zoölogical garden was an animal prison where animals large and small were confined in cages just

large enough to permit them to turn around easily, and where the "convicts" dragged out a miserable existence for a few years until relieved by death, seldom leaving offspring to inherit their unhappy fate. Today, in gardens such as those in New York and Washington, the animals are kept, as far as may be, in large open enclosures, where they can live under as nearly natural conditions as possible. Under such conditions they are healthy and contented and frequently rear families.

But the New York Zoölogical Society has not confined itself solely to the show business. Its studies of wild life have been its most valuable contributions both to science and popular education, and today our inhabitants of land and sea, our dwellers in forest, field, and lake and river are becoming objects of familiar acquaintance through the writings of Hornaday, Ditmars and Townsend, as well as through the splendid collections at the "Bronx" and the "Battery" in New York City.

A recent and important enterprise of the Society is the Tropical Research Station at Kalacoön, near Georgetown, in British Guiana, with C. W. Beebe, curator of birds at the New York Zoölogical Park, as its director. The object of this station is a study of life in the tropical jungle, with the more ample equipment of the permanent laboratory taking the place of the scanty means of the exploring naturalist, through whose labors our knowledge of tropical life has thus far mainly been acquired. The recent establishment of this station, with its more or less improvised equipment, has not led to any large results thus far, although a number of delightful essays by the director recently published under the title of "Jungle Peace" form a distinct contribution both to literature and to popular science.

The first botanical garden in America was that of John Bartram in Philadelphia, to which brief reference has been made in the previous chapter.

One of the pioneer figures in American botany was Geo. Engelmann, the St. Louis botanist-physician, contemporary of Gray at Harvard and Torrey at Columbia. Engelmann had a friend in Henry Shaw the wealthy merchant and lover of plants. During his extensive travels in Europe Shaw formed the idea of a botanical garden at his country place on the outskirts of St. Louis. From Engelmann he obtained advice and encouragement, and through him started a library and herbarium. Upon Engelmann's death in 1885 Mr. Shaw founded the Henry Shaw School of Botany in Washington University and in it established the Engelmann professorship in memory of his friend and tutor. On Mr. Shaw's death

the garden passed into the hands of a board of trustees to be administered as a public garden and a research school of botany.

On this foundation has risen the Missouri Botanical Garden of the present, with its splendid conservatories and herbarium; its library containing among thousands of modern botanical works some of the rarest of those dealing with the earliest studies on the exploration of plant and animal life in America; and its research laboratory where the faculty and graduate students of botany in the university may



A GLIMPSE OF THE NEW YORK BOTANICAL GARDEN

Courtesy of the Garden.

prosecute their studies. The popular conception of a botanical garden as that of a museum of living plants for display purposes is admirably realized in the arboretum and conservatories of the garden, while the less popular, but far more important function of research is equally well performed in its well equipped laboratories. The field of activity covered by the garden is limited only by the bounds of botanical knowledge. No problem is too abstruse or too practical for its attention. In all of its educational features, in display as well as in research, the Garden occupies one of the most important places in American botany.

Similar in conception to the Missouri Botanical Garden is the New York Botanical Garden in the Bronx Park in New York City, which was established in 1891 through the initiative of the Torrey Botanical Club, which takes its name from one of its founders, the pioneer botanist, John Torrey, who, like others of his early colleagues, was well versed in other sciences than that in which he earned his reputation. Commencing his career as a physician he subsequently became professor of the natural sciences at West Point, the



A VIEW OF THE ARNOLD ARBORETUM WITH BANK OF LAUREL ON THE LEFT
Courtesy of Professor Sargent.

College of Physicians and Surgeons, the College of the City of New York, Princeton and Columbia, and was for many years assayer in the New York assay office. On Torrey fell the duty, among others, of working up the collections of plants gathered by the many exploring expeditions, which at this time were pushing the frontier of America out through the trackless west.

On the outskirts of Boston is one of the most beautiful and unique collections of plants in the world. The Arnold Arboretum is the joint product of Boston and Harvard



A BIT OF THE "FOREST PRIMEVAL"
A hemlock grove in the Arnold Arboretum.
Courtesy of Professor Sargent.

University. It was established about fifty years ago by a gift of \$100,000 by James Arnold of New Bedford, and the setting apart of a tract of some 200 acres by joint arrangement between the city and the university. It forms at the same time a part of the splendid park system of Boston, and a "museum of living trees." Here are gathered together trees and shrubs from temperate climes in all the world, the old New England hemlocks, a bit of the "forest primeval" of the Pilgrim fathers, the firs and spruces of the Rocky Mountains, the oaks of England, the cedars of Lebanon, and the funereal cypress of China, with roses and cherries from far away Japan.

In the arrangement of the grounds formality has been thrown to the winds. Well trimmed lawns, rows of trees and flower beds with square corners have been subordinated to Nature's beautiful carelessness in the planning of the gardens. And yet through all the apparent disorder, there runs an orderly arrangement whereby related plants are brought together, and each family of tree and shrub has its own appointed place in the general plan.

Under the direction of Professor Sargent, head of the Arboretum, has been developed a museum, library and herbarium containing specimens of the wood of all American trees, showing its structure when cut with or across the grain, and when polished or smooth. There are records also of the physical character of different woods, their specific gravity, heat value, amount of ash, etc. The herbarium contains a collection of woody plants from all parts of the world, while the library is one of the best collections on trees in existence.

From the Arboretum have come Professor Sargent's "*Silva of North America*," a classic on American trees. Here too was written his "*Forest Flora of Japan*," the result of extended travel and research in that country. As author of the report on our forests in the tenth census, the director of the Arboretum brought to the notice of the people of the United States their wonderful, but rapidly vanishing timber resources, and paved the way for the development of forest conservation and the establishment of our forest reserves.

The Arboretum also has served as pioneer and guide in the establishment of botanical gardens elsewhere, both private and public, aiding notably in the development of the New York Botanical Garden. Many new importations from abroad have been tested here, including those of commercial as well as artistic value. Of these might be mentioned among many others, the tung oil, lacquer, pistachio and hardy rubber trees of China, brought from the Celestial Kingdom by the

indefatigable and hardy explorer of the Arboretum, Mr. E. H. Wilson.

Devoted to the study of biology, both here and abroad, are numerous institutions or biological stations, which have, and are exercising a wonderful influence upon its growth.

An exact definition of a biological station is impossible. The term is generally referred however to institutions, apart from college laboratories, dealing usually with aquatic biology and often operating only a part of the year, but such a definition is by no means exclusive.



THE MAIN BUILDING OF THE MARINE BIOLOGICAL LABORATORY AT WOODS HOLE, MASS.

This is perhaps the leading center of biology in America and one of the foremost in the world. There gather here each summer many of the leading biologists from all parts of the United States; and in it have been made some of the most important discoveries in biology.

In America the seed from which biological stations have sprung was the primitive laboratory of Louis Agassiz at Penikese, conducted during the summer of 1873; where in an old barn, with the twittering swallows flying in and out beneath the eaves, and from whose open door a glimpse of cloud-flecked sky and foam-flecked sea could be seen across the heather, this great student-teacher gathered a little band of enthusiasts to catch the fire of his imagination and carry it throughout the land. Anointed with the spirit of the master

this little group of apostles went forth to spread his teachings across America, and a Jordan and a Brooks have passed the torch to their students, and they in turn to others in an ever widening circle of living truth.

The laboratory at Penikese was abandoned the following year owing to the death of Agassiz, but a worthy successor was soon to follow in the Marine Biological Laboratory at Woods Hole, which was founded in 1888 by Professor Alpheus Hyatt of Boston, and a group of naturalists and their friends.



WOODS HOLE, MASS.

In the middle background is the "Fish Hawk," and to the right the buildings of the U. S. Bureau of Fisheries. In the foreground is the sea bottom with a group of its inhabitants.

Courtesy of the American Museum of Natural History.

For many years the work at Woods Hole was, and to a large extent still is conducted in flimsy wooden buildings, of the cheapest sort of temporary construction. But in 1914 through the generosity of Chas. R. Crane, the patron saint of the laboratory, a substantial and commodious building was erected, which is well furnished with modern equipment in biology.

A detailed account of the work at Woods Hole would require several volumes in itself, and is out of the question here, but its principal results are mentioned elsewhere in

connection with the general account of biological progress in America. Its character has been as varied as that of the men who have conducted it, a list of whose names would include



TYPICAL WHARF PILE COMMUNITY OF THE NEW ENGLAND COAST

Submerged timbers form the home of a wide variety of sessile animals including sponges, hydroids, sea anemones, barnacles, mussels and sea squirts. The immobility of the anemones and hydroids, and their delicate flower-like habit, led the great Greek naturalist, Aristotle, to give the name of zoöphytes (animal plants) to these and similar forms. It was such surroundings as this which attracted Agassiz to Penikese.

Courtesy of the American Museum of Natural History.

the leaders of American biology from the Atlantic to the Pacific and from Canada to the Gulf of Mexico.

Woods Hole may well be called the "Naples of America," the Mecca to which in ever increasing numbers biologists make pilgrimage each year. Who that has been there does

not carry away with him a memory and an inspiration? A memory of the "hole" with its foaming eddies, of the "eel-pond" with its landing stage and launches, and the "stone building" where the genial head of the supply department presides over an incongruous medley of flopping dogfish, five-rayed starfish and bristling sea urchins, which the "Cayadetta" has just brought in from the fish trap in Buzzard's Bay, or dredged from the rocky bottom of Vineyard Sound. A memory of wind swept heath, where the song sparrow rears its brood, of gently curving beach, white shining in the summer's sun; of rocky headlands, where the seaweeds grow and the sea anemone clings fast to its home uncovered by the falling tide; of the lighthouse on the point and the buoy with its never silent bell; of white sails upon the Sound, and the dim shores of Martha's Vineyard fading into the soft gray blue of the summer haze and sky. An inspiration of the bigness of things, of all there is to do and the joy of doing, of knowledge sought for the sake of knowing, a touch of the fire from the altar of Penikese, lit by the hand of Agassiz, the master.

Fast following the pioneer of biological stations in America came a number of lesser stations, at first along the Atlantic seaboard, and later in the Mississippi Valley, on the shores of the Pacific, and in the Rocky Mountains. These, for the most part, have been merely summer schools conducted in conjunction with the department of biology in some college or university. In some however notably La Jolla, Calif., Havana, Ill., and Casco Bay, Me., the emphasis has been placed upon research, and much original work of great value has been done. The first of these, under the title of the Scripps Institution for Biological Research, because of the generous patronage of a wealthy La Jolla family, is an adjunct of the Department of Zoölogy of the University of California. In the earlier years of its existence it was, so to speak, a traveling laboratory, occupying temporary quarters at various points on the California Coast and finally locating permanently at La Jolla. The Scripps Institution is one of the few biological stations in the country whose physical equipment is adequate to the work it tries to do. The laboratory building is simple, almost to harshness in its architecture, in fitting harmony with the barren landscape round about; but its interior appointments and equipment are very complete. Its principal efforts thus far have been directed to the study of the smaller marine animals or plankton of the southern California Coast, and the factors in their environment which determine their distribution, but attention has also been turned in recent years to certain land

animals (wood mice of the genus *Peromyscus*) and the influence of climate on their evolution. The Scripps Institution is probably unique among similar institutions in America in the enlistment of both private and public agencies in its support. Recently the legislature of California has contributed substantially to it and this in spite of the fact that its work is avowedly of a purely scientific character, and that no attempt has been made to arouse interest under the specious plea of some practical end to be gained at some future time.

"Two years ago when the first allotment was made by the state to the university for the institution, and this year when an increase was asked, representatives of the state visited the institution, went over with the scientific staff and business manager in considerable particularity the work being prosecuted, and were unequivocally assured that the problems under investigation are all first and foremost scientific, and that only some of them might be expected to have a money value to the state.

"Great emphasis was, however, laid by the men of the institution on the two facts that all increase of knowledge of nature is capable of being made useful to the people of the commonwealth in one way and another, either for their enlightenment or pleasure or material gain; and that the institution holds itself under as much obligation to make its discoveries utilizable in some form as it does to prosecute the investigations themselves. . . . From what California has done toward maintaining the Lick Observatory through a considerable term of years, and is now doing for the Scripps Institution, the conclusion seems justified that the state is definitely committed to the principle of state aid to scientific research, even though such research has no direct and primary industrial aims. In discussing these matters with officials, I stoutly contend that in the long run about the most telling criterion of success of popular government will be the extent to which it contributes to the highest development, spiritual and physical, of the naturally best endowed persons who live under and who participate in such government. The facts and reasonings that can be presented in support of this proposition, particularly those touching the question of leadership in scientific discovery, seem to appeal with special force to men grappling earnestly with the practical problems of government for a modern community.

"Experience strongly inclines me to the view that the serious dereliction of our national and several state governments in the support of scientific investigation is chargeable quite as

much to scientific men themselves as to government officers and the people at large." ⁴

Surely it is cause for congratulation to science in general, and to this institution and its director in particular, when our strictly practical legislators can be made to see the value to the state of science for its own sake.

In addition to the Scripps Institution several other laboratories have been privately endowed within recent years. Apart from the Marine Biological Laboratory at Woods Hole, which is of much longer standing, these laboratories



BUILDINGS OF THE STATION FOR EXPERIMENTAL EVOLUTION OF THE CARNEGIE INSTITUTION AT COLD SPRING HARBOR, L. I.

Here are being conducted important researches into the laws of inheritance in plants and animals, and in conjunction with this station the Eugenics Record Office is laying the foundation for an intelligent treatment of marriages and the breeding of a better human race.

After Davenport. Year Book of the Carnegie Institution for 1914.

have contributed more to biology than all other biological stations in America combined, and their promise for the future is correspondingly greater. These are the three biological laboratories of the Carnegie Institution and its Department of Embryology, and the Rockefeller Institute for Medical Research. It is true that the latter is primarily a medical institution, as its name implies, but the intimate association of medicine with biology, and the fact that one of its departments is devoted exclusively to biology, entitles it

⁴Ritter in "Science," Vol. XLII, 1915, p. 245-246.

to consideration here. The Wistar Institute of Anatomy in Philadelphia, and the Bussey Institution of Harvard University should also be included.

The three Carnegie stations are known respectively as the "Department of Experimental Evolution" at Cold Spring Harbor, L. I., the "Department of Botanical Research" at Tucson, Ariz., and the "Department of Marine Biology" on the Dry Tortugas Keys off the Florida Coast. These were all established between 1903 and 1906, shortly after the founding of the Institution by Mr. Carnegie. The first of these is, as its name implies, devoted to a study of evolution and its twin sister, or better, its right hand, heredity. As early as 1617 Francis Bacon advocated an institution for studying evolution experimentally, but not until the early years of the twentieth century was his suggestion realized. Its major work has been the study of inheritance in many kinds of animals and plants, the influence of external factors, such as alcohol, light, etc., upon the structure and evolution of animals, the influence of selection in evolution, the rôle of the chromosomes in inheritance, and the underlying factors of sex.

The physical equipment of an institution such as this emphasizes the specialization of biology today, and its dependence upon other sciences. Apart from the usual apparatus of the biological laboratory and the extensive pens and stabling required for housing the stock, there is an artificial cave with aquaria for studies upon cave animals, a well equipped chemical laboratory, and constant temperature rooms arranged in pairs, one pair for dry and one for moist air, so that experimental animals can be kept in warm or cold, dry or moist chambers.

The site of the station and the adjoining laboratory of the Brooklyn Institute of Arts and Sciences are the picturesque shores of Cold Spring Harbor, a long narrow inlet from Long Island Sound. On the opposite shore is the straggling little village of the same name, which in days gone by was one of the whaling ports of Long Island.

Perhaps the most important outcome of the station's work has been the Eugenics Record Office, established at Cold Spring Harbor in 1910, through the generosity of Mrs. E. H. Harriman. The function of the Office is the recording of human inheritance, to the ultimate end of gaining greater knowledge thereof, which may lead to its improvement. It collects records of family traits, which records are kept in a sextuple card index of persons, traits and localities; enabling an investigator to readily trace a given trait in both the families and the localities of its occurrence, to determine the

families and traits occurring in any locality, and finally to find the location of a given family and the traits peculiar to it. The Office has extensive collaboration with charitable and penal institutions throughout the country, by means of which it obtains very valuable data regarding the occurrence and inheritance of many defects in man, both mental and physical; and finally it conducts a training school for workers in human inheritance, with a view to preparing them for service in such institutions.

Baked in the scorching rays of the Arizona sun lies Tumamoc Hill, the Hill of the Turtle in the Navajo tongue.



DESERT BOTANICAL LABORATORY

The deserts of Arizona have been invaded by the biologist, offering as they do a specially attractive field for studies of the influence of environment on both animals and plants. At this station of the Carnegie Institution of Washington at Tucson, Arizona, many important discoveries have been made as to how plants adapt themselves to a desert environment.

Courtesy of the Bureau of Commerce of Tucson.

On its slopes, covered with the rocky débris of some convulsion of the earth long past, grows the giant cactus, gaunt and misshapen by day, spectral and weird by night. Its summit overlooks a tumbled junk heap of hills and hollows suggestive of the thought that the Creator became hurried at the last moment and did not have time to put the finishing touches on the wilderness. At its foot lies the Santa Cruz Valley with the city of Tucson, and across the valley, sharply outlined against the deep azure of the desert sky, rise the bold commanding shapes of the Santa Catalina Mountains, with

the lure of the forest and its cold fresh streams within their depths.

Here has the Desert Laboratory of the Carnegie Institution found its home in a long, low stone building on the summit of Tumamoc Hill, with an adjoining greenhouse, and a small photo-chemical laboratory nearby. The efforts of the Department have been devoted to a study of desert⁵ conditions and their effect upon the plant life of the region. In conjunction with a small branch laboratory at Carmel, near Monterey, California, extensive studies have been carried on upon the influence of climate on the form of plants. Various species of plants have been transplanted from their cool, moist home in the Santa Catalina Mountains to the experimental gardens at Tucson, and vice versa, and interchanged between the Arizona Desert and the cool, damp California Coast with consequent marked changes in their form. In order to see how "the other half" of the plant world lives, expeditions have been sent to the Sahara Desert, and the tropical forests of Jamaica. Studies on the revegetation of the Salton Sea area have been carried on for several years. This is a brackish water lake in southern California, originally over 400 square miles in extent, which was formed in 1905 by the overflow of the Colorado River through an irrigation canal leading to the Imperial Valley. In the arid climate of southern California this lake has fallen to about one-half its original depth of 84 feet, leaving wide stretches of lake bottom exposed, where new vegetation may arise. From such studies much can be learned as to the development of plant life in our arid southwest.

At one time Great Salt Lake extended over a much wider area than now, reaching an extent of nearly 20,000 square miles, and a depth of 1,000 feet, as can be determined by the old shore lines on the mountain slopes in northwestern Utah. To this greater Great Salt Lake the name of Lake Bonneville has been given, from the doughty captain, whose wanderings in the far west have been so picturesquely portrayed by Irving in his "Captain Bonneville." To the southwest of Lake Bonneville stretched the wide expanse of Lake Lahontan, named from the explorer La Hontan. In the heyday of their existence, following the retreat of the ice of the Glacial period, these lakes received a copious supply, but Nature early put into effect some "bone dry laws" in this region, and now the site of Lake Lahontan is an arid waste clothed in sage brush and cactus and inhabited by the coyote, prairie dog, burrowing owl, rattlesnake and horned toad, with here and there ■

⁵The term "desert" as applied to this region is a misnomer; arid tableland or steppe would be better.

lonely, but optimistic ranchman and a few salt ponds, remnants of its former glory; while Great Salt Lake is but a vestige of its former self.

Today one may find in Salton Sea a repetition of the story of Lakes Bonneville and Lahontan, while on its shores Nature is showing us how she clothes the desert.

We are all familiar with the "oldest inhabitant" and we enjoy listening to him as he smokes his pipe and conjures up memories of the past through the curling wreaths of blue smoke, but we are wont to be a bit skeptical when he tells us of the "old-fashioned New England winter," when fences presented no barriers to the sleighs, and the farmer had to tunnel through snow in the morning to reach the barn, and feed his cattle. But now comes the scientist to the aid of the "oldest inhabitant" and tells us that after all climates, like peoples, do change, and that the pictures of the "good old days" may not be as highly colored as we sometimes fancy them to be. To gain his information Professor Ellsworth Huntington of Yale has quite rightly gone to the "oldest inhabitants" of America, dwellers of the forest, some of whom were living at the time of Moses, and were creatures of antiquity in the days of Jesus Christ. To most of us indeed the Sequoia, or California "big tree," is a veritable Sphinx, a creature of the past whom we revere both for its lordly mien and its great antiquity, but one with whom we cannot hold converse. But Professor Huntington has learned to read the "riddles of the Sphinx" and in his monograph on the "Climatic Factor" he has told us its story. Each year's growth of a tree leaves its mark upon its stem in the form of a ring of wood, so that, not only does the stem give us a record of the age of the tree, but also of the amount of each year's growth, which is measured by the thickness of the ring. From a study of the stumps of many fallen trees, Professor Huntington has reached conclusions relative to the "fat years," when the trees made a good growth, and the "lean years" of the past, when growth was slight. But the amount of growth of a tree depends upon the amount of moisture which it receives, and thus Professor Huntington has determined the relative amounts of annual rainfall for several thousand years in the past.

But not alone in the trunks of the big trees can the story of the past be read. In the waters and the old shore lines of lakes may a record too be found. The water of every river contains a certain amount of dissolved substances, washed from the land by rain, which finds its way as "run-off" into the rivers. Thus through countless ages has the ocean acquired its salt, the contribution of land to sea. When a lake

has both inlet and outlet, its water is being continually changed, and consequently it contains nearly the same amount of salt from year to year. But if a change of climate occurs, so that evaporation exceeds precipitation, the lake begins to shrink, its outlet is lost and the salts which are carried into the lake by its tributary rivers accumulate, and a little inland sea is formed. Thus have arisen the various salt lakes and inland seas such as the Caspian, the Dead Sea and Great Salt Lake. If now we measure the amount of water carried by the tributary rivers of a closed lake, and determine the amount of salts carried by them, we can estimate the number of years



SHORE OF SALTON SEA, SHOWING OLD LAKE LEVEL IN BACKGROUND

The character of the beaches of extinct lakes gives a clue to the weather of the past.

After MacDougal.

required for the lake to acquire its present degree of saltiness since the time when it had an outlet. Such measurements are at best approximate, due largely to the fact that when rainfall was greater the rivers carried a greater amount of salt than they do at present, but when compared with the testimony of the old shore lines, they furnish a means for determining probably to within 50 or 100 years the periods of heavy and light rainfall in the past.

These ancient lake beaches can often be traced for miles with the greatest ease. When a lake maintains the same level for a number of years it leaves an unmistakable record "on the sands" or gravels "of time" in a clear-cut beach or terrace, where the waves have undermined and cut away the

banks, and the stronger the wave action, the more clearly marked will the terrace be. When, on the other hand, the lake is receding, the terraces will be wanting or ill-defined, and the shores gradually sloping. Thus a series of terraces, in an old lake basin, with intervening slopes, means a succession of alternating wet and dry periods in the past, during the former of which the water supply was sufficient to maintain the lake at a constant level, while during the latter the level was steadily falling. Still further evidence may be obtained from submerged forests. The bottom of Stump Lake, N. Dak., at one time part of the much larger glacial lake, Minnewaukon, was years ago covered by a forest, as is evidenced by the stumps, many of which are still lying on the old lake bottom, now being exposed by the progressive shrinkage of the lake from excessive evaporation. This forest contained trees probably very similar to those at present growing about the lake shore. Thus, within comparatively recent times,⁶ Stump Lake was successively part of a considerable body of water, then dry land (at least in part, the extent of the submerged forest not being known) for a sufficiently long period to allow of the growth of forest trees of considerable size; again it became a lake submerging the forest and now for the second time it is disappearing. This evidence is borne out by terraces beneath the present lake level and by piles of boulders in the lake which show evidence of the work of ice in their formation.

And so Professor Huntington and his colleagues have called upon Pyramid and Winnemucca Lakes, in western Nevada, remnants of the old glacial Lake Lahontan, and Owens and Mono Lakes in California to testify; and their evidence has supported that of the "big trees," and the words of earth and tree have in their turn been verified by the pages of history. According to the evidence it is about 2,000 years since these lakes had an outlet, so that during the Christian era they have been gradually shrinking, oscillating up and down with the varying rainfall of the centuries.

"The lakes do more than indicate a change of climate within two or three thousand years. They also show that the change has been highly irregular. This is proved by a large number of strands lying below the level of the outlets, and by the way in which these vary in character and in the extent to which they have been covered by fresh detritus washed down from the mountains. At Owens Lake there are four series of strands. These apparently correspond to the four chief periods when the climate has grown moist as shown by the growth of the big trees. . . . Fortunately, Owens Lake

⁶ Since the Glacial Epoch.

lies only fifty miles east of the region where the trees were measured. The general climatic fluctuations of both districts are the same. The uppermost strand, the huge gravel beach at the level of the outlet, must date from about the time of Christ, for both the chemical evidence and the trees point to this conclusion. A series of similar, but much smaller beaches at lower levels record the approach of a dry period during which the lake fell to a low level whose exact position cannot be determined. Judging by the trees this must have culminated about 650 A.D. During this period gravels were washed in by mountain streams and deposited in what are known as fans, or low, flattened cones, which may be several miles long. These covered the old strands in many places, and extended far below their level to the diminished lake.

"Next the waters rose again, but not halfway to their former level. They formed two small strands, not gravelly like their predecessors, but faint and sandy as if the winds were weak. They must date from about 1000 A.D., when the trees indicate a wet period, for they are younger than the gravel fans of the preceding dry time. The next phase of the lake was a dry period, which was most extreme about 1250 A.D. More gravels were then deposited, and the fact that they cover the preceding strands and extend to a much lower level shows that the lake then stood low, as would be expected from the trees.

"The next high period of the lake, about 1350 A.D. according to the trees, is unusually interesting. The water did not reach so high a level as formerly, because the rainy period was short, but it formed a large, high beach of gravel quite different from the preceding beaches. This seems to indicate great storminess, a condition which is also suggested by the fact that the growth of the trees at this time increased more rapidly than at any other period for nearly 3000 years. In Europe during the same century, unprecedented storms caused great floods in France, while the severity of the waves was so intense as to break through beaches and sand dunes, and convert large marshy areas into portions of the sea along the coasts of Holland and Lincolnshire. During the winters the rivers froze to an unheard-of degree, and three or four times men and animals passed from Germany to Sweden on the solid ice of the Baltic Sea, an occurrence unknown in our day. In England the summers were so rainy that the average yield of grain diminished disastrously. In self-defense many landowners gave up grain-raising, and turned their attention to sheep and cattle. Distress and discontent were the inevitable result among the peasants. Far away in central Asia the Caspian Sea and the lake of Lop Nor both rose with great

rapidity between 1300 and 1350 A.D. Thus from California to China evidence of various kinds unites to indicate that during the fourteenth century there occurred a short period of unusual storminess. Such conditions, if intensified and prolonged, would probably cause the accumulation of enormous glaciers." 7

Professor Huntington's studies on the influence of climate upon human life form one of the most interesting and valuable contributions to history of recent years. He has shown for example that the wonderful civilization of the Mayas in Guatemala and Yucatan, in a region where today death stalks through the jungle and human energy is at its lowest ebb, is explicable on the hypothesis of a different climate in these regions in past years, an hypothesis supported by his evidence obtained from lake and tree. He has similarly traced the history of man in Asia and Europe and likewise discovered there the profound influence of nature upon his ways. These climatic changes appear to be in some way determined by solar activity as evidenced by the number of "sun spots." But these most interesting hypotheses would lead us too far aside from our proper path were we to pursue them further.

Much of Professor Huntington's work was carried on through the Department of Botanical Research, and his results are among the most interesting and valuable of its contributions to science.

On a small tract of land in the Santa Cruz Valley belonging to the Department are the experimental gardens, where for a number of years Professor Tower of the University of Chicago has been conducting his experiments on the potato beetles, reference to which is made elsewhere. In the physico-chemical laboratory extensive investigations are in progress on the physical and chemical factors involved in the process of photosynthesis; or the work of the sun through the chlorophyl of the green plant in taking the raw materials of earth and air and water and constructing from them the starches and the sugars which the plant uses as its food. Many other are the activities of the Department which occupies a unique and indispensable place in American research.

Surrounded by the blue waters of the tropical sea, scorched by the sun, deluged by the torrential rains and swept by the cyclones of the tropics lie a string of little islands off the southern extremity of the coast known as the Florida Keys. On one of the groups, named by the early Spaniards, from the abundance of their aboriginal inhabitants, the sea turtles, the Dry Tortugas, is located the Department

⁷ Huntington, "Civilization and Climate," pp. 235-7. By permission of the Yale University Press.

of Marine Biology of the Carnegie Institution. Surrounded by coral reefs, where lurk the countless denizens of the southern seas, in a healthful environment, and with the resources of the Carnegie Institution behind it, the Tortugas laboratory has enjoyed a situation unique in the history of biology. How well it has profited by this opportunity can best be told by the results which it has produced, many of which are referred to in other chapters without especial



THE GARDEN OF THE TORTUGAS LABORATORY

Much has been done to render this wind-swept isle a spot of beauty. The coral reefs surrounding these islands abound in tropical plants and animals, many of great beauty and all of fascinating interest.

Courtesy of Dr. A. G. Mayer, Director of the Laboratory.

reference to the source whence they have come. It would be impossible in this place to mention these results in detail, or even to single out those of seemingly most importance. No general line of research has been pursued, the only limiting conditions being that the researches should be devoted to problems of tropical life.

In addition to the local researches of the laboratory, visits have been made in its staunch little ship, the "Anton Dohrn," to distant regions, through the Caribbean Archipelago, to Jamaica, Porto Rico, and even to the Great Barrier Reef of

Australia, to study how the world is made, at least that part of it contributed by corals.

While our knowledge of the structure of the human body is more complete than that of any other animal, our information regarding the beginnings of man is extremely fragmentary. As a matter of fact our knowledge of man's earliest stages is a blank. The reasons for this state of affairs are sufficiently evident. For many years anatomists have been striving to



THE YACHT, "ANTON DOHRN," OF THE CARNEGIE STATION ON THE TORTUGAS ISLANDS

Named after the founder and life-long head of the world-famous station at Naples, Italy.

Courtesy of Dr. A. G. Mayer, Director of the Tortugas Station.

supply the deficiencies in our knowledge by collecting human embryos and fetuses, and one of the leaders in this effort was the late Professor Mall of Johns Hopkins University. In the course of many years Professor Mall brought together some 2,000 embryos and fetuses, and his studies of them have thrown light, not so much on the unknown stages of human development, as upon many curious malformations in man, which are apt to occur in the material which the anatomist secures, and knowledge of the causes of which are of the high-

est importance in our efforts toward the making of a better human race.

In 1913 this work was taken over by the Carnegie Institution and organized in its Department of Embryology, which was under Professor Mall's direction until his death in 1917, and since then has been conducted by his successor, Dr. Geo. L. Streeter. The work of the department, while not limited to human development, has that as its focal point.

When Dr. Casper Wistar was teaching anatomy at the University of Pennsylvania in the early part of the last century, and discussing with President Jefferson the bones of the mastodon which the latter had discovered in Shawangunk County, N. Y., he little foresaw the institution which the future was to raise upon the foundation he was laying. The collection of anatomical specimens which he gathered has since grown into the splendid museum of the Wistar Institute in Philadelphia, founded by Dr. Wistar's grand-nephew in 1892. While the Institute was established primarily as a home for the Wistar Museum, its usefulness has far outgrown the function of mere display. In research, and especially as a center for dissemination of its results through scientific journals, it fills a place unique in American science.

While its researches have been largely of a technical character, chiefly upon the nervous system, they form the basis for future investigations, which are likely to prove of the highest importance to man. The rat has been used as the experimental subject for these researches. For this purpose the Institute maintains a rat colony of many thousand individuals, and from April, 1917, to April, 1919, it furnished thirty-five thousand rats to government and other laboratories, or one rat every thirty-five minutes during this period. A comparison of the growth of the body as a whole, of the nervous system and of twenty other organs in rat and man, has shown a general similarity in both animals, if comparison be made at the same relative stage of development in both. The rat grows approximately thirty times as fast as man and lives approximately one-thirtieth as long a life (three years). The rat is weaned at twenty days, man at fifteen months while the development of the nervous system is approximately the same at this age (i.e. when weaned) in both animals. Similar studies, both of the nervous system and of other organs, have given similar results. The rat furthermore is almost as omnivorous as man, and requires much the same food constituents to keep him healthy.

If then the growth of the nervous system in the rat can be increased for example by exercise or retarded by poor food, we may logically expect similar results in man. To

solve these problems the Institute is beginning a series of studies upon man in the training school for the Feeble Minded at Vineland, N. J., where records are being made of the growth, behavior, and clinical history of some four hundred inmates. In conjunction with this work post-mortem examinations will help to explain human behavior in terms of the structure of human tissues, both normal and diseased; while continued studies of the rat will, it is hoped, throw further light upon the influence of an animal's surroundings on its structure and activities.

The effect of inbreeding in plants and animals is at present but little understood. The general belief is that its results are highly injurious to the offspring. In some species of plants however we find special devices of nature to insure self-fertilization, and the results of inbreeding various kinds of domestic animals and plants are by no means uniform in showing its harmful character. It has been stated that among the Ptolemies and the Incas marriage of brother and sister frequently occurred, while in ancient Persia the marriage of parent and child was permitted.

Hence the studies which Dr. King has been carrying on at the Institute for several years upon the effect of continued inbreeding on the growth, health, fertility and sex ratio of animals, are of peculiar interest. As a result of these studies, which are the most extensive hitherto made, Dr. King finds that mating of brother and sister rats for thirty generations produces no ill effect upon fertility and general health of the offspring, provided the best animals are selected for breeding.

One of the most important and interesting researches of the Institute has been its studies on the refractive index of the blood serum, which has been shown to differ, not only at different ages, but also under differing conditions of health and disease. Thus blood from persons afflicted with syphilis, tuberculosis, cancer or Bright's disease, has each its own characteristic index; and the method, which is very simple, gives promise of being a very valuable aid in the diagnosis of disease.

In the publication of journals the Institute performs one of its greatest services to biology. The publication of such journals, with their limited circulation, is always difficult financially; but by systematizing and standardizing its methods for several of them the Institute has been able to reduce the expense of publication to a minimum, while at the same time increasing their circulation and widening their influence throughout the world. In 1919 nearly five thousand copies of five journals were distributed to libraries and individuals in virtually every country in the world, at a net

expense of only about \$6,000 annually. In addition to this it publishes a card index with a brief abstract of every article published in its journals as well as in several published elsewhere.

In 1901 there was established in New York City an institution unique in character and destined to do more in alleviating human suffering than any other institution in America. While the Rockefeller Institute was founded primarily for medical research, its department of experimental biology under the direction of Jacques Loeb is devoted to the study of biology pure and simple, and is furnishing biologists with an ample supply of food for thought as well as controversy. Its departments of physiology, bacteriology and protozoölogy have also made invaluable contributions to biological science. In the field of medicine proper the unique feature of the institution is a splendid hospital, in charge of a staff of highly trained experts, the majority of whom are devoting their entire time to this work, concentrating their efforts at any given time on special diseases and with the resources of the experimental laboratory at their command.

Thus far the diseases selected have been of common occurrence, including some of the worst scourges of man, such as infantile paralysis, syphilis, pneumonia and spinal meningitis. Bulletins are issued at intervals by the director of the hospital informing physicians of the diseases selected for study at any given time.

Patients are admitted to the hospital from all classes of people, rich and poor alike, without charge. In some cases however wealthy patients have been permitted to donate money to the hospital in recognition of their indebtedness for its services. But although the services of the institution are freely given, and while its primary function is the study of disease, the right of the patient to receive the best possible treatment is fully recognized, and no one on entering the Institute surrenders in any way his right to such treatment.

An important feature of the Institute's work is the publication of the "Journal of Experimental Medicine," which is one of the leading medical journals in this country, and includes in its pages much material of primarily biological interest as well.

In addition to its studies upon human diseases the Institute maintains a department of animal pathology at Princeton, N. J., where animal diseases are being investigated.

There are many other institutions in America devoted to the study of special diseases, such as the Henry Phipps Institute of Philadelphia for the study of tuberculosis and the Barnard Free Skin and Cancer Hospital of St. Louis. Their

work however is primarily medical in character, and limits of space prohibit further mention of it here.

On a fine old estate in Forrest Hills, a suburb of Boston, at one time the residence of the late Benjamin Bussey, is the Bussey Institution, an adjunct of the department of botany and zoölogy in Harvard University, where much of the pioneer work in genetics in America has been done. Forest conservation and increase, and insect control also form part of its program. The purpose of Mr. Bussey, the founder of the institute, was to support the teaching of agriculture at Harvard. His funds are now being devoted almost wholly to research in subjects fundamental thereto, reference to some of which is made in other chapters.

A fourth class of institutions which have contributed in no small measure to the great structure of American biology, are the biological bureaus of the U. S. Government—the Bureau of Fisheries, of Animal and Plant Industry, of the Biological Survey and of Entomology; but inasmuch as their work has been mainly along economic lines, it may best be discussed in another chapter.

In these few pages have been briefly sketched the history and scope of American biological institutions. Much has of necessity been omitted, but it may be that enough has been given to outline the extent to which wealth and human effort have been expended in this broad and fertile field.

CHAPTER III

Descriptive biology. Development of plants and animals; of sex, and sexual reproduction, and alternation of generations. The path of vertebrate evolution.

Science as we have seen is cosmopolitan and impossible of limitation by geographic lines. Especially is this true of descriptive biology. With the increasing specialization of modern science it is to a certain extent possible for one man or a group of men to work out more or less independently some particular problems or group of problems of far-reaching interest and importance. Thus our knowledge of animal reactions we owe largely to Jennings, Rhumbler, Mast and Loeb; the physiology of digestion immediately calls to mind the epochal work of Pavlov, while Chittenden's researches have made scientific nutrition matter of household knowledge. The new science of genetics we owe largely to the work of Bateson, Punnett, Cuenot, Castle, Davenport and Morgan, while the structure and function of the cell, have been in great part unraveled by the skillful touch of Wilson and Boveri. To a certain extent this is likewise true of purely descriptive biology. Amphioxus and the name of Willey are indissolubly linked together in our minds; the oyster has been exhaustively studied by Brooks, the alligator by Reese, the Ascidians by Ritter and the crayfish by Andrews. We have the splendid researches of Allen, Merriam and Stone on the classification, distribution and habits of birds and mammals; those of Jordan, Dean and Eigenmann on fishes, of Mayer on Medusæ and of hosts of other specialists on various groups of animals and plants; while the names of Osborn, Cope and Scott will ever be associated with the extinct life of ages long gone by. Many of these studies however are of but small value in themselves. Information as to the structure, classification and distribution of a given organism or group of organisms, gives us comparatively little information as to the great laws of life, except in so far as these facts are correlated with similar facts relative to other groups of organisms, whereas the research in physiology (using this term in its broadest sense) of a single man, may lead to discoveries of profound and far-reaching

significance. And thus it comes to be that the whole fabric of morphology, or the science of form, is a mosaic of individual bits of knowledge, some greater, some less, but none of great importance except when considered in relation to all the others. Of what particular interest for example is the discovery of a connecting ligament between the arteries which supply the lungs and those which supply the trunk in higher vertebrates, apart from the existence of a functional blood vessel representing this ligament in some of their more lowly aquatic cousins (the lungfishes and *Amphibia*)? Or how can the parts of a flower be understood without a knowledge of the process of reproduction in the ferns and mosses?

To follow adequately the course of descriptive biology in America would carry us too far afield, and into paths wherein many of us perchance would not care to wander. We may however trace in a few words some of the main lines of morphological research, noting the discoveries to which they have led and the problems which still confront us.

Since Darwin's epoch-making work, the golden thread of evolution has linked together the labors of morphologist and physiologist alike, and the efforts of the former have centered around the genealogies of living things. What have been the lines of ascent from the one-celled animals and plants to those of many cells? Are animals and plants of common ancestry or do they belong to two distinct groups of living things, each with its own origin? What has been the origin of the germ layers and the coelome in animals, and how have those of many segments become modified to those of few? How can sexual be related to non-sexual forms, and hermaphroditic to those of separate sex? What is the origin of alternation of generations, and how has the non-sexual gained so great an ascendancy over the sexual form in higher plants? These are a few of the great questions which the morphologist has to answer. In this solution however he must call to his aid the experimenter, for after all observation and experiment are but two phases of the same science, working together toward a common end.

All living things may be divided into the two great groups of the one, and the many-celled, the Protozoa and Protophyta on the one hand, and the Metazoa and Metaphyta on the other. Each many-celled animal or plant begins its career as a single cell, containing within itself all the possibilities of the adult plant or animal. So too does the one-celled organism contain the possibility of evolution into a new creation of beings yet unknown. Most of these lowly creatures to be sure have deviated from the straight and narrow path

which leads to high estate, and have wandered off into byways of specialization, some of which may perchance cause their undoing and lead to their extinction.

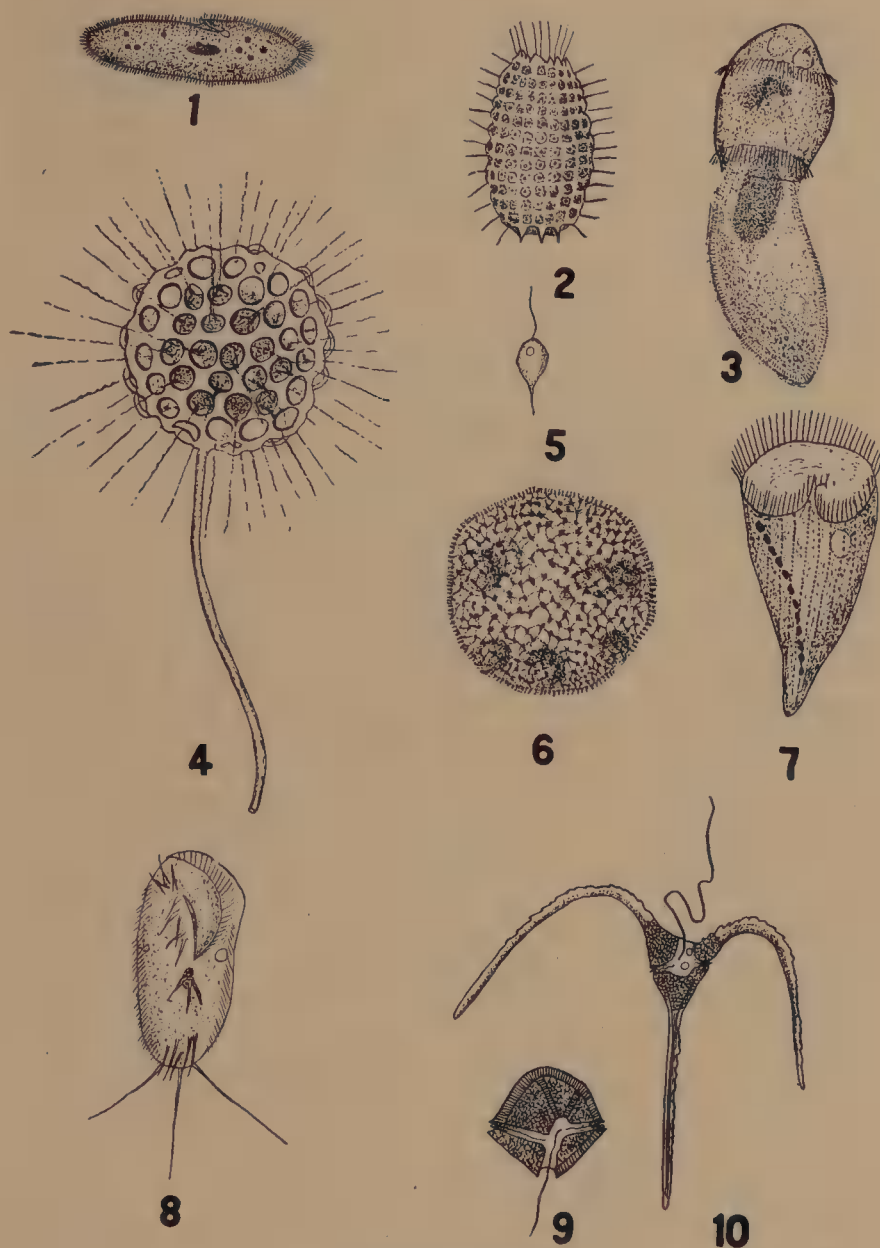
If one go to any wayside pool or pond, gather a handful of weeds and allow them to stand in a laboratory jar for a few days, he will soon have a new creation at his hand, a little world of swarming life, tense with the keen struggle for existence. Here he will find dwarfs and giants, the tiny "monad" and the sac-like Bursaria which reaches the rela-



PROTOZOAN TYPES

1, Dileptus; 2, Trachelophyllum; 3, Bursaria. After Conn.

tively enormous size of one-twelfth of an inch; and all the bizarrerie of evolution running riot. One shaped like a ribbon, yet others like cornucopias or bells, and still others with long, extensile necks, veritable giraffes of the microscopic world. One great group of Protozoa, the ciliates, derives its name from the delicate rapidly beating processes or cilia which cover the animals, and by means of which they move so rapidly through the water as to drive many an amateur microscopist to drink, in desire at least, if not in practise. In many of these the cilia, instead of being uniformly distributed over the body, are limited to definite areas. Occa-



PROTOZOAN TYPES

1, *Paramecium*; 2, *Coleps*; 3, *Didinium* feeding on *Paramecium*; 4, *Clathrulina*; 5, a monad; 6, *Volvox*; 7, *Stentor*; 8, *Stylonichia*; 9, *Peridinium*; 10, *Ceratium*.

Figs. 2 and 8 after Conn; 4 after Leidy; 5 and 7 after Edmondson; 9 modified from Schilling after Huitfeld-Kaas; and 10 after Lankester; the rest original; 3 from a preparation by Powers.

sionally they form one or more rings about the body, while again they are condensed into several long flexible processes by means of which the animal crawls about over the weeds or bottom. Still others possess long slender spines, which may either have no apparent use, or may serve as springing organs, the animal lying still for a time and then suddenly starting to roll and tumble about as though possessed of a very devil of unrest.

Yet another great group of Protozoa, the flagellates, derive their name from the flagella or whip-like processes by means of which they swim. Most Protozoa are actively motile, but some are attached by stalks, either singly or in branching groups. These are sometimes fixed, and sometimes furnished with delicate muscle fibrils, which contract suddenly when the animals are disturbed.

Usually naked, some Protozoa are enclosed in cases or shells. One lives in a tube, with a lid which closes as the animal retracts, and opens as it expands. Many of these shells are of great beauty and complexity. The infusorian *Coleps* bears a shell comprised of numerous plates arranged in circles around the body, the flagellate *Peridinium* has a delicately sculptured shell of twenty-one plates and *Ceratium* is enclosed in a shell bearing long, horn-like processes. But the most remarkable development of shells is found in the Foraminifera and Radiolaria, whose remains form so large a part of the ooze covering the bottom of the sea, and which have produced valuable deposits of building stone and chalk in the past.

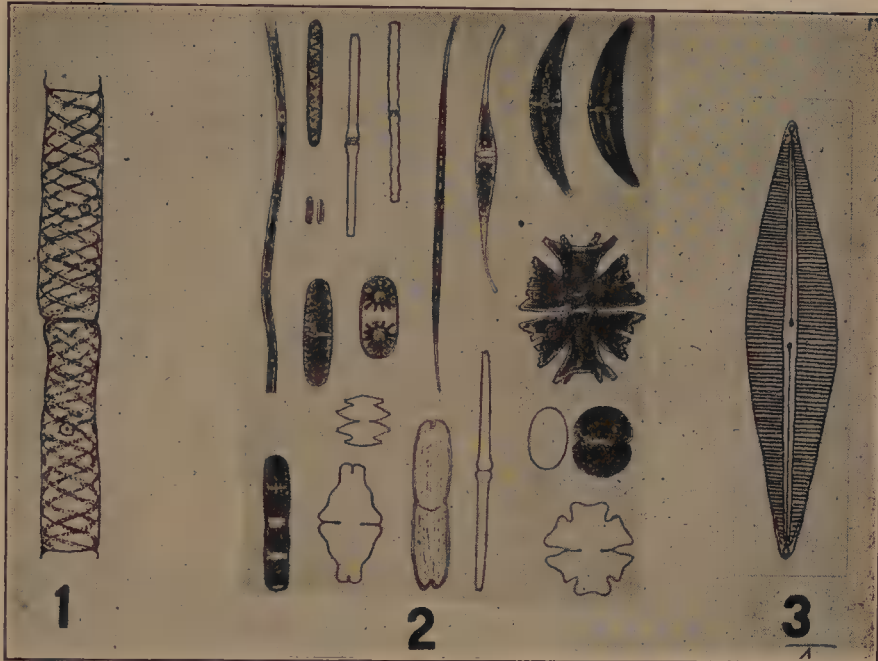
Many Protozoa have developed primitive organs of digestion, excretion and respiration, while some have contractile fibrils in the outer layer of the body, which serve as primitive muscles. Yet others have the suggestion of eyes in the form of pigment spots, which doubtless are responsive to light.

In these early differentiations of structure we have forecast for us the conditions in the Metazoa or many-celled animals with their special organs and corresponding "division of labor" or work which these organs have to do.

Not alone in structure are many Protozoa highly specialized. In manner of life they vary widely. Many of them are exclusively marine, others inhabit only fresh waters, while still others may be found in fresh and brackish water alike. Mostly free living, a few have developed the habit of commensalism, or close association with some other organism. The ciliates, *Trichodina* and *Kerona*, are usually found gliding over the surface of the fresh water polyp *Hydra*. The Radiolaria harbor symbiotic algæ, by means of which the synthesis or construction of carbohydrates is possible, after the manner

of the green plant. Yet others contain within themselves the magic chlorophyl, whose beautiful green delights our eyes in the early verdure of the spring, and by whose means Nature performs her wonderful chemistry, converting carbon dioxide and water into sugar, which plants and animals alike may use as food. Many, notably the Sporozoa and some flagellates, are parasitic, and in some cases are the cause of plagues of man and beast.

In the world of the little as well as in that of the great,



LOWER PLANT LIFE

1, Spirogyra; 2, desmids; 3, a diatom.

1 and 3 original, 3 from a preparation by Elmore, 2 from Needham & Lloyd's "Life of Inland Waters," Comstock Publishing Company.

we find the rôle of the hunter and the hunted. Usually it is the smaller fry which are the victims, but sometimes it is they which take the hunter's part, attacking and destroying animals much larger than themselves. Chief among these is Didinium, a little creature about $\frac{1}{150}$ inch in length with a boring proboscis by means of which it attacks and engulfs other Protozoa from three to six times as large as itself. The customary daily ration of this little gourmand is one or two Paramecia, but when especially hungry it may consume as many as four or five of these animals.

As protection against their insatiable foes many Protozoa

have developed structures known as trichocysts, or secretions contained in the surface protoplasm, which when ejected form a mass of tangled threads and serve as an abatis to repel the attacker.

Among the unicellular plants also high degrees of specialization occur, which are represented mainly by variations in general body form, by development of shells, filaments and spines, and by changes in chromatophores and nuclei. Typ-



AMŒBA PROTEUS, ONE OF THE MOST PRIMITIVE TYPES OF LIFE

Photograph of a model in the American Museum of Natural History in New York.

Courtesy of the Museum.

ically spherical or ovate in form the algæ may become linear, club-shaped, discoid, spiral or crescentic, while the shell markings of desmids and diatoms are among the most delicate and beautiful objects of microscopical study.

The chromatophores or chlorophyl carriers of the algæ are one of their most specialized features. In its simplest form the chromatophore is disk- or plate-like, but it varies from the more generalized form to the specialized star-shaped, spiral or netted ones. Typically possessing but a single nucleus,

the algæ may have many or none. In the latter condition, shown by the bacteria and blue-green algæ the nucleus probably consists of numerous granules scattered throughout the cell.

While the majority of unicellular organisms show a more or less high degree of specialization, there are a few which still remain more nearly in what was undoubtedly the primitive condition and which may therefore be regarded as possessing greater possibilities of advance to higher types. Such among animals is the *Amœba*, while among plants the most primitive are the *Protococcaceæ*. The minute flagellate forms known by the non-committal term of "monads" are undoubtedly however very close to the bottom of the ladder of life, and it is quite possible that they represent the starting point for both animals and plants. Whether these primitive forms are very ancient, representing the direct descendants of the original progenitors of living things, or whether they are recent, and represent one of many evolutions of living from lifeless matter is an interesting problem for speculation, but one offering small possibilities of solution with our present knowledge. In view of the great variability of most forms of life the likelihood of any group of organisms persisting with but little change throughout biologic time seems most improbable. But on the other hand we have no evidence of the origin of living from lifeless matter at the present time, and we know further that some forms of the present day (i. e. *Spirifer*, one of the *Brachiopoda*) are indistinguishable save in minor characters from their representatives of the Cambrian period, which may have lived some four hundred millions of years ago.

Among both the *Protozoa* and *Protophyta* are many species, in which the cells instead of remaining distinct are grouped in colonies. In many of these the association is loose and indefinite, the group increasing in size for an indefinite time and finally breaking up to form other groups. This is especially true of the numerous filamentous algæ, but is also true of other algæ and *Protozoa*. In some however notably in the *Volvocaceæ* the size and the number of cells comprised in the colony is more or less definite, foreshadowing the conditions in the many-celled animals and plants.

Among both unicellular plants and animals reproduction occurs typically by simple cell division. At the time of division the parent cell loses its identity but does not die, continuing to live in its two descendants. The theoretical possibilities of increase of these microscopic forms are beyond our powers of imagination. According to Professor Morgan, a protozoan *Stylonichia* "produced in 61½ days a mass of

protoplasm weighing one kilogram. At the end of 30 days, at the same rate, the number of kilograms would be 1 followed by 44 zeros, or a mass of protoplasm a million times larger than the volume of the sun."¹

But in many of these forms another process of reproduction has developed, wherein two cells, or in any event two nuclei play a part, a process known as conjugation or fertilization. A simple example will illustrate this. If a single individual of the ciliate *Paramœcium* be placed in a suitable culture fluid it will divide rapidly, forming in a few days a countless progeny. After a time if one examine a drop of the culture he will likely find some of the individuals united in pairs. They remain thus united for possibly 24 hours, after which they separate and each resumes its rapid multiplication. Briefly told, what happens during their union is as follows: *Paramœcium* contains two nuclei, a larger, or macronucleus and a smaller, or micronucleus.² The latter divides three times and several of the parts thus formed disappear, but two remaining. Of these one, the larger, remains quiescent, while the other migrates across the protoplasmic bridge uniting the two animals and fuses with the quiescent nucleus in the other cell. This fusion nucleus then divides several times, some of the daughter nuclei enlarging to form new macronuclei which are distributed to the daughter cells, the old macronucleus having disappeared in the meantime. Some of the daughter nuclei degenerate, while one remains to form a new micronucleus. We have here probably the beginnings of sex as indicated in the difference of size and activity of the two micronuclei, which fuse with each other during the cell union. Externally however sexual difference between the cells is not evident.

The meaning of this process is not clear. It has been supposed to have a rejuvenating influence upon the cells taking part in it, but this interpretation is rendered doubtful by recent experiments of Professor Jennings at Johns Hopkins, who suggests that it is rather a means of producing variation and thus leading to evolution.

The union of similar gametes or reproductive cells is common among the algæ. Frequently these cells bear cilia and are motile, while the ordinary form is non-motile. In some cases a slight difference in size between the conjugating gametes is suggestive of the differentiation between egg and sperm cell of higher forms.

¹These figures are given by Morgan in "Heredity and Sex." He disclaims responsibility however for the mathematical computation involved.

²There may be one or two of these latter.

A still further stage in sex development is shown by a distinct difference in size and activity of the copulating cells. The malaria organism multiplies asexually in the blood cells of its host. After a time, under conditions not well understood, some of the malarial cells enlarge. If now the patient is bitten by one of the *Anopheles* mosquitoes, which transmit the disease, some of these enlarged cells remain quiescent, forming the female cells in the mosquito's stomach, while others cast off a number of small active filaments or male cells. These latter then unite with or fertilize the former,



LIFE CYCLE OF THE MALARIAL ORGANISM

a, parasite in red blood corpuscle; b and c, spore formation; d, female, and e, male cells, which are uniting at f; g, sporozoites in cyst; h, sporozoite free; i, ameboid parasite developed from h, prepared to enter red blood corpuscle, j. Original.

and from their union a large number of minute motile cells or "sporozoites" are formed, by which the asexual cycle is repeated when the infected mosquito bites a new victim.

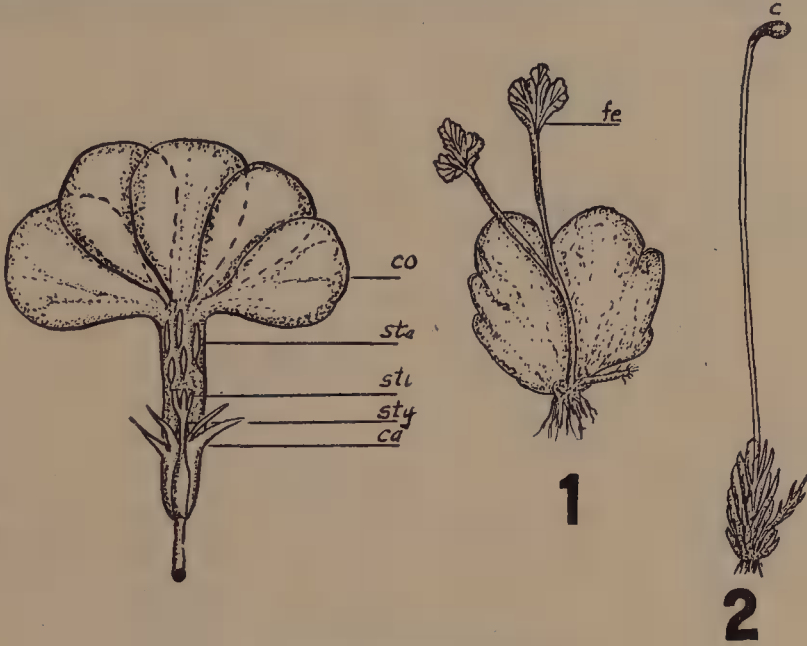
Yet a further and final step in sex differentiation among the unicellular forms is found in *Volvox*, an organism which is on the fence, so to speak, between Protozoa and Protophyta; and which forms a bone of contention between the botanists and zoölogists, each claiming ownership to it. *Volvox* is a hollow spherical group of cells, numbering in some cases over 20,000, and reaching a diameter of $1/25$ of an inch. The cells carry a pair of cilia each, by means of which the organism is

an active swimmer. They also contain chlorophyl, enabling it to manufacture its own food, so that physiologically it is a plant, but in respect to the possession of cilia, and a red eye spot which is sensitive to light, it resembles more nearly an animal. Its reproduction is partly asexual and partly sexual. In the former method, some cells multiply to form secondary colonies, which lie in the cavity of the mother colony and finally break through its wall to form new colonies. In the latter, certain large cells lacking cilia are differentiated as eggs, while other cells divide to form a varying number of motile sperms. Fertilization results in the formation of a resting cell or "zygote," which after a period of inactivity develops into a new colony.

In definiteness of form, close association of cells and especially in the differentiation of sexual cells, *Volvox* stands as a stepping stone between the unicellular types with their typically asexual reproduction and the many-celled forms which typically reproduce by fertilization. In yet another respect does *Volvox* approach the higher types. Some species are hermaphroditic, producing both eggs and sperms in the same colony, while in others the two sexes are lodged in separate individuals. There are many other forms, both single-celled and colonial, which resemble animals in having flagella and eye-spots, and plants in possessing chlorophyl. Sometimes it is only the reproductive cells which have all of these features, the ordinary cells being typical algæ with chlorophyl but neither flagella nor eye-spots. It is possible that the "monads," to which reference has already been made, have developed chlorophyl, giving rise to the plant kingdom, on the one hand; and have assumed an ameboid form, producing the animal kingdom on the other. This is suggested by the occasional occurrence of flagellates which are either ameboid at all times, or may assume an ameboid form at certain times in their life cycle.

Through the entire series of plants from the lowest to the highest runs a curious phenomenon known as alternation of generations, or the alternate succession of sexual and asexual methods of reproduction. How many of us stop to think when we pluck a violet or smell a rose that the flower was not made to delight our eye or nose, but has developed as a means for the perpetuation and increase of its kind? And how does the flower perform its function? Hidden away at its center, where but few of us ever see them, are the female organs or ovaries, bearing at their summits little processes known as styles, which end in small expansions, the stigmas. Surrounding the ovaries are a ring of delicate filaments, the stamens, each bearing at its tip a sack, the anther. In the

anther the pollen grains are formed, and these when ripe are scattered by the wind or carried by insects to another flower, where, lighting upon its stigmas, they germinate and send fine tubes down through the styles to reach the ovaries at their base. Through these tubes pass the male nuclei formed within the pollen grain, which unite with the female nuclei within the ovaries, the pollen tube representing the last remnant of the body of the sexual plant in lower forms. Similarly there are contained within the ovary, beside the



REPRODUCTION OF PLANTS

Left: A phlox blossom showing flower parts. Ca, calyx; co, corolla; sta, stamens; sti, stigma; sty, style. Original.

Right: Alternation of generations in 1, fern, showing the sexual form or prothallus bearing the asexual fern, fe; and 2, moss, showing the spore capsule, c.

female nucleus, several nuclei, which represent the body of the female sexual plant in mosses or in ferns.

The moss plant is the sexual form, which bears the egg and sperm producing organs. From the egg, after fertilization in the ovary springs a slender stalk bearing a capsule at its summit. When this is ripe it bursts, casting forth the tiny spores, which generating give rise in turn to the sexual moss plant. Similar conditions obtain in the liverworts. In these forms therefore the gametophyte or sexual plant is the chief generation, the sporophyte or asexual form the smaller, secondary one.

In ferns the reverse is the case. If one examine the under-

side of an ordinary fern leaf he will find its edges pimpled with rows of little brown capsules somewhat smaller than a pin head, which on bursting scatter to the wind a fine brown dust. This consists of the spores, which after germination produce a leaf-like body, the prothallus, about a quarter of an inch in diameter. This is the gametophyte, which bears the sexual organs. It grows only in moist places, moisture being necessary for the transfer of the sperm to the egg. From the fertilized egg develops the sporophyte or ordinary fern plant, thus completing the cycle in the life of the fern.

Alternation of generations also occurs in some algæ. Here it is the gametophyte which is the conspicuous plant, the sporophyte being usually a smaller structure.

Passing upward from the lower to the higher plants we see then the sporophyte progressively increasing and the gametophyte decreasing in importance.

While alternation of generations is characteristic of plants it occurs occasionally among the many-celled, as well as in unicellular animals. Many of the delicate and beautiful jelly-fish, with which any observant visitor to the seashore is familiar, are the sexual phase of the life cycle of an animal whose asexual form consists of an attached series of disks, which in the course of development separate from one another to form the sexual form or medusa. In certain marine worms (Polychæta) also alternation of generations occurs. The anterior part of the body does not develop sex organs, while posteriorly the worm divides into several parts, which becoming sexually mature separate from the parent stock to form the sexual generation. In some of the curious "sea squirts" or tunicates also this process is found.

The tunicates derive their name from the mantle or tunic surrounding the body. Some are fixed, and others free swimming as adults; while in the former the animal is frequently free-swimming as a larva. The name of "sea squirt" is derived from the habit of the fixed forms of squirting out a stream of sea water when touched.

The larva of the fixed forms is totally different from the adult and the true relationships of the latter could not be understood were it not for the existence of the former. This is a tadpole-like animal with a long tail through which runs a supporting rod, the notochord. At the anterior end of the animal is an adhesive disk by means of which it attaches itself at the time of metamorphosis. The wall of the pharynx is perforated by a number of openings or gill slits which lead into a waste chamber or atrium opening to the exterior by a pore. Dorsal to the pharynx is a nervous mass or primitive brain, and between the two a small duct opening into the

former which is known as the "sub-neural gland," and has been compared to the vertebrate hypophysis, which is part of the pituitary body or gland attached to the base of the brain, one of those problematic organs of "internal secretion" which is playing so large a part in medicine today. The larva swims actively by means of its long tail, but at metamorphosis the latter is lost together with its supporting rod or notochord, and the animal abandons the wandering ways of youth and settles down to its future monotonous existence.

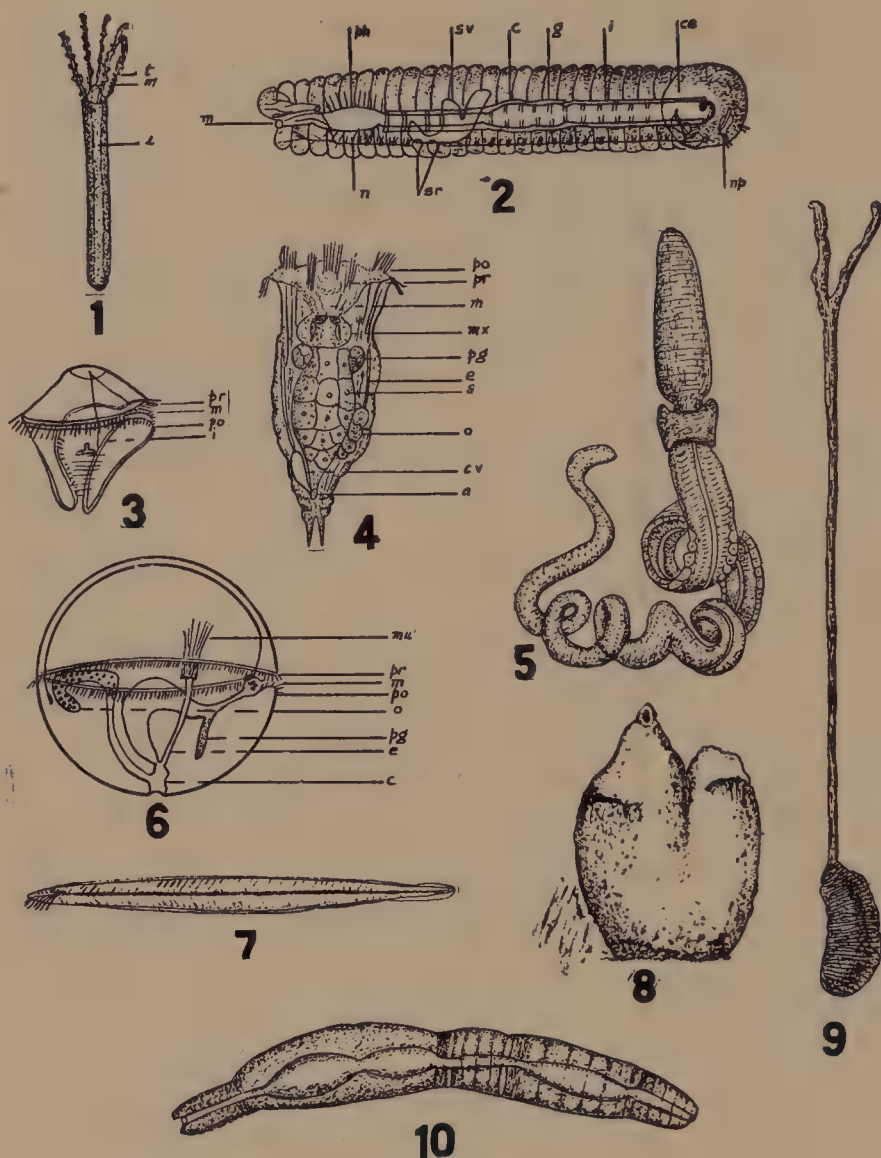
In those tunicates in which an alternation of generations occurs, the asexual form gives rise by budding to a colony of "zooids" which more or less directly produce the sexual animals.

The meaning of this strange and interesting life history remains for the future to disclose. Until we understand the underlying significance of sex, it is hopeless to attempt to solve the riddle of alternation of generations. In our attempt to find an answer to both of these two great questions of biology, the experimental, rather than the purely morphological method gives the greater promise of success. There is already at hand evidence to show that the appearance of sexual reproduction can be to a certain extent at least controlled by experiment. Details regarding such experiments may be postponed however to a later chapter.

The most likely interpretation of alternation of generations however is that it is a "device" of Nature to increase the spread of the species and thus enhance its chances of survival. It occurs typically in attached forms such as most plants, and the hydroids, Polyzoa and some tunicates among animals, while in those marine worms in which it occurs the asexual generation often lives a retired and inactive life in the recesses of some rocky shelter, only the sexual generation swimming freely at the surface of the sea. It obviously increases the chances of distribution of a fixed form to have a sexual free-swimming form which may carry the reproductive cells and scatter them far and wide. A difficulty in such an interpretation however is that in some of these forms the sexual generation is not free-swimming but attached to the asexual one. This may of course be a degenerate condition.

In the case of the plants on the other hand, it is the asexual form with its numerous spores, which is most important in the distribution of the species, these spores being readily carried by the wind and thus better suited to spreading a land form, than the flagella-bearing sperms, which require water for their distribution.

Among the Protozoa alternation of generations frequently



INVERTEBRATE TYPES

1, Hydra; 2, earthworm; 3, a trochophore larva; 4, a rotifer; 5, Balanoglossus; 6, Trochosphara; 7, Amphioxus; 8, a tunicate; 9, Bonellia; 10, a fresh water annelid reproducing by fission. Fig. 3, from Korschelt and Heider after Hatschek; 4, from K. & H. after A. Agassiz; 6, from K. & H. after Semper; 9, from Doncaster; the others are original, 9 from a preparation by Powers. Fig. 1, i, intestine; m, mouth; t, tentacles. Fig. 2, c, crop; ce, coelome; g, gizzard; i, intestine; m, mouth; n, nerve cord; np, nephridium (kidney); sv, seminal vesicles; sr, seminal receptacles; ph, pharynx. Figs. 3 & 4, a, anus; cv, contractile vesicle or bladder; e, excretory duct; i, intestine; m, mouth; mx, mastax (grinding pharynx); pr, pre-oral, and po, post-oral ciliated rings; pg, pharyngeal glands; s, stomach; o, ovary. Fig. 6, c, cloaca; e, excretory duct; m, mouth; mu, muscle; pr, pre-oral, and po, post-oral ciliated rings; o, ovary; pg, pharyngeal gland.

occurs, especially in the parasitic forms. Here the production of numerous spores undoubtedly increases the distribution of the organism, but the meaning of the sexual phase in the life cycle is as obscure as is that of sexual reproduction among living things in general. The whole problem of reproduction, in all its manifold phases is one of the most perplexing which biology has to solve.

In the majority of animals the sexes are distinct, but in some, notably flat worms, annelids, some molluscs, etc., they are found in the same individual, which is then known as an hermaphrodite from *Hermaphroditus*, the Son of *Hermes* and *Aphrodite*, who became joined in one body with the nymph *Salmacis*. How comes it that in some animals we find distinct sexes, while in others, not distantly related to them, they are united? Here again we are face to face with one of Nature's inscrutable mysteries. A possible clue is found however in the fact that in animals of separate sex, the early stages of the sex organs may be apparently "indifferent," that is, neither male nor female, becoming differentiated into either sex as development proceeds. Even though sex may be, as we shall see later, predetermined in the fertilized egg, nevertheless all the essential parts of both male and female may develop in the embryo. Furthermore, there are many instances, some of which will be mentioned in another chapter, of so-called "sex intergrades" where the animal or plant may be predominantly of one sex and yet show some of the characteristics of the opposite sex; and further, when the sex glands cease to function, either from disease, removal or old age, certain characters of the opposite sex may appear, as noted in a later chapter.

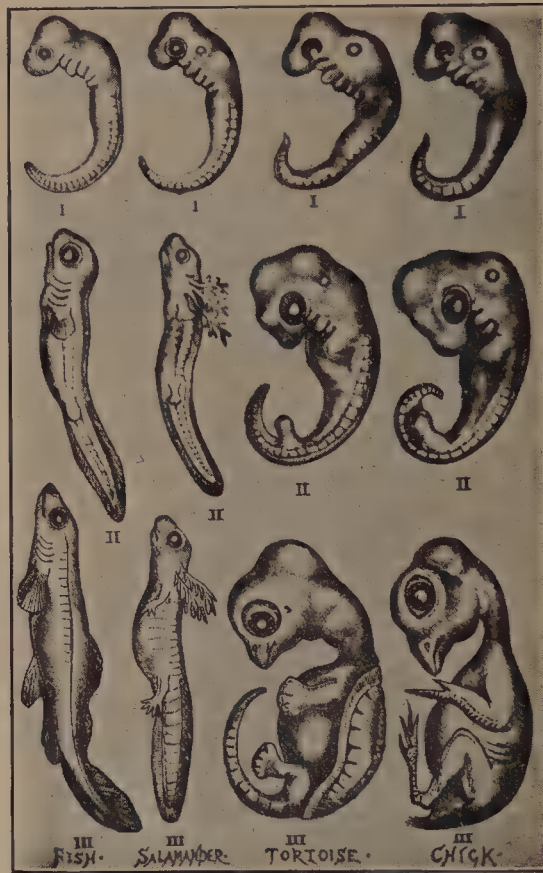
Apparently then the hermaphroditic condition is primitive and the bisexual one derived, through suppression, but not loss in either sex of the characters peculiar to the opposite sex.

But why this differentiation has occurred and the advantage thereof we do not know.

Passing from the unicellular to the multicellular animals or Metazoa we find one of the simplest of the latter in a little creature which strangely enough bears the name of the many-headed monster, *Hydra*. Its body consists of two layers of cells and contains a primitive digestive cavity with a mouth, which is surrounded by several tentacles, giving the animal its fanciful resemblance to the horrid monster of fabled story. The space between the layers contains an almost negligible jelly and the muscle processes of cells lying in the two layers.

From *Hydra* the next step in advance is very uncertain. The reader may best be spared the mental contortions neces-

sary to follow the feats of the imagination performed by the morphologists in leaping the gap between Hydra and higher animals. Suffice it to say that an imaginary ancestor has been created to serve as the starting point of the latter, from which these have diverged, each upon its several way.²



A SERIES OF VERTEBRATE EMBRYOS

I, II, III, 1st, 2nd, and 3rd stage. From Romanes "Darwin and After Darwin."

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If one compare a series of the early stages of animals, which in the adult form are widely different from one another, he may find it difficult or impossible to tell them apart. The embryos of fish, frog, bird and mammal are almost identical with one another at a certain stage of development.

²The above statement must not be interpreted as an oversight of the higher cœlenterates and the ctenophores. But even taking a ctenophore as a "jumping off point" there is still a wide and as yet unfathomed abyss to cross.

Man begins his life as a single cell, corresponding to the protozoan stage of evolution. Later he consists of two layers of cells, corresponding to a greatly modified Hydra. Then he possesses three "germ layers" and numerous segments like a worm, from which stage he passes to that in which he has gills like a fish, and later on a tail and coat of hair like a monkey.³ These and many other facts of like nature have led to the law that the development of the individual is a replica in miniature of the development of the race, a law which has been much abused by its friends no less than by its enemies. While this principle is unquestionably sound it must not be pushed too far. In its main features the development of the individual does reproduce that of the race, but in all its details certainly not. At no time in his development does man ever resemble an adult fish, but there are certain stages in development which are common to both; man in his earliest stages having certain fish-like features.

To follow the trail of animal evolution through the development of the individual calls for all the cunning of a biological Sherlock Holmes. Nature has, as it were, cleverly concealed her footsteps, and made many a false move to throw the pursuer off the track. But her trail is there and can be followed if we have the necessary acumen and patience.

In the development of many worms, molluscs, echinoderms, tunicates and other invertebrates there occur certain larval forms known as trochophores. All trochophore larvæ are by no means alike, but all have the same general plan of structure, and the presence of these larvæ in the development of so many different groups of invertebrates has led to a belief in an ancestral "trochophore" from which these groups have radiated, like the spokes about the hub of a wheel.

Very closely resembling in many respects the trochophore larva is the group of rotifers or "wheel animalcules" so called because of the circles of rapidly beating cilia leading to the mouth, which in their activity resemble the motion of a wheel, and by means of which the rotifer obtains its food and swims through the water. One of these, *Trochosphæra*, resembles the trochophore larva in its general form so closely, as to have misled some biologists into the belief that this was an ancestral type, and that the rotifers were the hub of the animal universe. But the absence of a body cavity renders such an interpretation more than doubtful, the rotifers having more likely been shoved off onto a side track from the main branches of evolution, where they stand, nearly related

³ This does not mean of course fully developed gills, tail and hair, but their beginnings may be seen. If the development of a fish or a mammal were arrested at a certain stage these organs would not be better developed in them than in man.

to the ancestral form, but not in the direct line of evolution of any of the higher types of animals.

Progressing upward from our ancestral trochophore, we come to forms whose general plan of structure is that of a double cylinder, somewhat flattened along one axis, with two sides alike giving it bilateral symmetry, and the upper or dorsal differentiated from the lower or ventral surface. The anterior end of this cylinder is differentiated as a head, with mouth, sense organs and primitive brain, while the posterior end lacks sense organs and contains an anus. The outer wall of this double cylinder is made up of "skin" and muscles, the inner is the wall of the digestive tract, with a body cavity or *cœlome* between. The cylinder is further divided into rings or segments, each of which bears one or more pairs of appendages for locomotion.

Of such a form the annelid worm, of which the common angle worm is an example, is typical, and from here onward in our progress to the vertebrates and man we are on surer, though still insecure footing. The annelid or annulate is as its name indicates a series of joints or rings, all more or less alike, which are very numerous in the typical form, but in the more specialized groups are greatly reduced. In fact, evolution from the annelid upward consists very largely in the concentration and specialization of these segments. While the annelids are probably not to be regarded as the direct ancestors of the vertebrates, their general plan of structure, with a *cœlome* and a segmented body, is fundamental to that of all higher types, even though it may be greatly modified in some.

The origin of the vertebrates is still shrouded in the mist of hypothesis and dispute, and indeed may ever remain so, since their invertebrate ancestors probably no longer exist. Nevertheless a clue to their origin may be found in the tunicates described above and in a little animal with a big name, *Balanoglossus*, or the acorn-tongue. This is a worm-like creature living in burrows in the mud or sand of the sea bottom near low tide level, and in its development passing through a trochophore stage. The anterior end is marked by a contractile and very sensitive proboscis, from the shape of which the animal derives its name, behind which is a collar region, which in turn is followed by the trunk. Between the proboscis and collar opens the ventral mouth which leads into the pharynx, which is perforated by a large number of paired openings to the exterior, the gill slits. Dorsal to the mouth is a diverticulum of the pharynx which projects into the proboscis, and which Bateson has identified as the notochord. The nervous system presents features of peculiar interest.

Its primitive character is evidenced by the superficial network of nerve fibres extending all over the body, and resembling in these respects the nervous system of a sea anemone. Along the mid-dorsal and mid-ventral lines this network is thickened to form definite nerve cords, thus relating the animal to the invertebrates with their ventral nerve cord on the one hand and on the other to the vertebrates, whose central nervous system is dorsal. This latter resemblance is still further enhanced by the hollow character of the dorsal cord in the collar region (at least in young animals) and its separation from the surface and deeper situation in the body in this region. The dorsal and ventral cords are joined by a ring surrounding the pharynx at the base of the collar similar to that of an annelid.

There are then certain points of fundamental importance which are common both to the tunicate and *Balanoglossus*, and to the vertebrates. These are the notochord, the gill slits and the dorsal nerve cord. The opposite position of the mouth in the two former (dorsal in the tunicate and ventral in *Balanoglossus*) introduces an element of uncertainty, and indeed the origin of the vertebrate mouth is a question of great difficulty. It is improbable that vertebrates can claim either the tunicate or *Balanoglossus* as a direct ancestor. In fact "direct ancestors" in the animal world are at a premium. In the very nature of the case, if living things are labile and not stabile, this must be so. Otherwise all organisms would become "stand patters" and evolutionary progress cease. But, regardless of direct ancestry, both of the organisms discussed show distinct vertebrate affinities and indicate the way which the latter have gone in their advance.

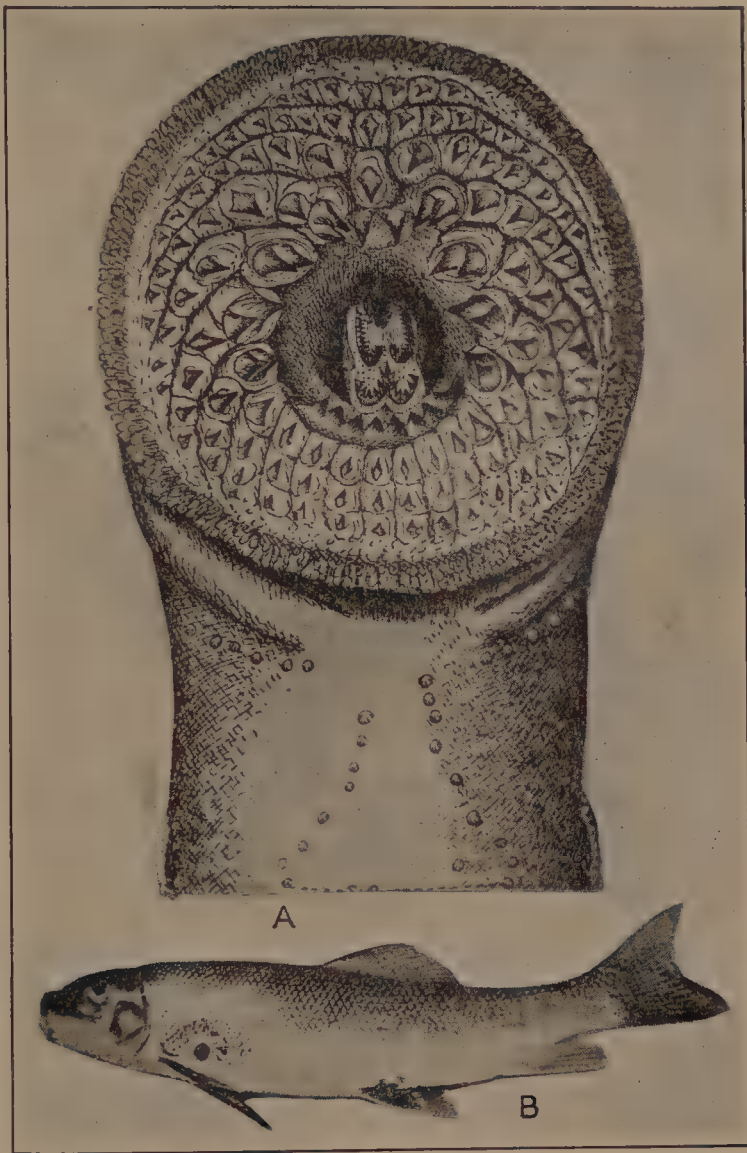
Further on the path of vertebrate development stands yet another sign post to mark the way. Burrowing in the sand of shallow seas throughout temperate and tropical regions is a little fish-like animal about two inches in length, which on account of its shape has been named *Amphioxus*, or pointed at both ends. Its world wide distribution in the face of its inadequate means of dispersal, and its comparatively slight specific differentiation, suggest that it is both a very ancient and very conservative sort of creature.

Running from tip to tip of the body extends a stiff rod which serves as a skeleton and aids it in its rapid burrowing in the sand. The body is marked by numerous V-shaped lines, indicating the divisions between the segments into which the muscles are divided. Just dorsal to the notochord is the hollow nerve cord from which paired nerves run to various parts of the body. Along this nerve cord are distributed numerous little spots of pigment, which probably give the animal its

extreme sensitiveness to light, to avoid which it quickly withdraws into its burrows in the sand. At the anterior end of the body are a number of delicate fingers or tentacle-like processes surrounding the mouth, which is ventral in position and which opens into the pharynx, whose walls are perforated by numerous gill slits, opening into a common branchial chamber or atrium. These are, briefly put, the principal features of this very curious and interesting little creature. In common with the vertebrates it has a hollow, dorsal nerve cord, a notochord and gill slits, while the absence of vertebræ and of anything resembling jaws, and its extensive segmentation relate it to invertebrates. Its organization is however distinctly more vertebrate in character than is that of either the tunicate or *Balanoglossus*.

The first of the vertebrates proper however are the cyclostomes, so named from their circular mouths, which lack jaws. They include both marine and fresh water forms and are dangerous parasites of fish, attaching themselves to the latter by means of the suctorial mouth, and rasping away the scales with their powerful tongue, armed with numerous horny teeth, and sucking the blood and soft tissues until their victim is destroyed. The hagfish *Bdellostoma* of the California coast is an example. This is an eel-like creature which is *persona non grata* to the Chinese fishermen, entangling their nets and destroying their fish. One individual in a pail of water will quickly convert it into a jelly-like mass due to the abundant slime secreted. In these animals we find the first typically vertebrate structure, namely the vertebral column, incorrectly called the "back bone," since it is not necessarily bony, but may consist of cartilage, and in some instances is not a continuous structure at all, but consists merely of a series of disconnected cartilaginous pieces, partially surrounding the nerve cord at the base of which lies the notochord. Whether or not the cyclostomes are primitive or degenerate types is a bone of contention among zoölogists. In their primitive vertebræ, persistent notochord, extensive segmentation of nerves and muscles and numerous gills their primitive character is clearly indicated; but in their suctorial mouth, and poorly developed eyes there is evidence of degeneration, correlated perhaps with their parasitic habits.

Not until we reach the true fishes do we find fully developed the vertebrate plan of structure, with a complete vertebral column built around and replacing the degenerating notochord, and surrounding the nerve cord; with paired upper and lower jaws and paired fins, and a fully developed brain case or skull. The origin of most of these structures is shrouded in mystery, and unless palæontology comes to our aid, re-



A. MOUTH OF LAMPREY

Showing the rasping tongue and toothed hood.

B. SUCKER WITH SCARS MADE BY LAMPREY

From Surface, "The Lampreys of Central New York," in Bulletin
U. S. Fish Commission for 1897.

vealing new links in the chain of life, it is likely ever to remain so. How arose the vertebrate mouth and jaws, through what steps has the skull evolved, how have the paired fins and their successors, the limbs, developed? These are some of the problems with which the student of vertebrate development has to struggle.

Is the vertebrate mouth a modified invertebrate one, and if so is it derived from the dorsal mouth of the tunicate or the ventral one of *Balanoglossus*, or was it made anew when the vertebrate was fashioned in Nature's work shop? Are the jaws new structures, *sui generis*, or are they second-hand gill bars employed by Nature for the purpose because they were the handiest structures she could find?

A possible clue to this question is found in the peculiar development of the anterior end of *Amphioxus*. When the mouth of this animal first appears it is not in its final position in the median plane of the body, but tilted far up on the left side, while *vice versa* the first gill slits make their appearance on the right side and secondarily are shifted over to the left. This larval asymmetry would be produced by any force twisting the anterior end from left to right; i. e., in the opposite direction to that in which the clock hands move. But if, as the result of such a twisting, the mouth is carried over to the left side its original position must have been dorsal. Now what evolutionary change could have produced such a twisting? In the early stages of the larva the notochord does not reach the tip of the body, only later extending there. Furthermore, neither in the tunicate larva nor in *Balanoglossus* does it extend to the tip of the body. If, in correlation with the burrowing habit of the animal, the notochord extended forward in the course of evolution, thereby stiffening the anterior end of the body, and aiding the animal to wriggle through the sand, the tendency would be to displace the anterior organs, and among them the mouth. Such an assumption seems very reasonable. If correct, then the mouth of *Amphioxus* must originally have been dorsal, and if this animal represents a primitive vertebrate type, then the vertebrate mouth must originally have had this position, secondarily migrating to the ventral side. But what of the origin of the jaws which are such characteristic features of all vertebrates above the cyclostomes?

As we have already seen a characteristic feature of all higher animals is their segmentation. This is seen in many parts of the body,—muscles, nerves, blood vessels, gills, etc. We have further seen that one phase of advance is the reduction in number of these segments and their specialization, or modification for the performance of other work than that

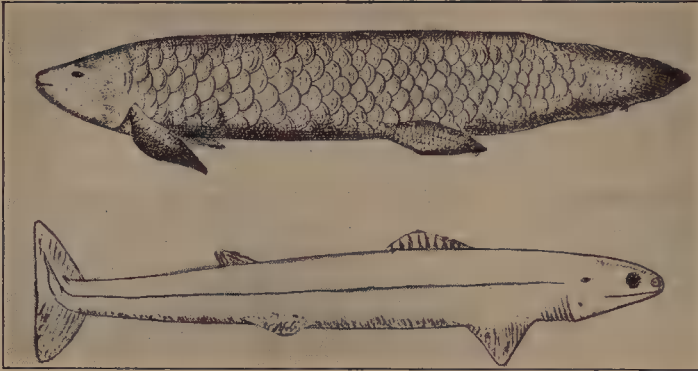
which they were originally called upon to do. In *Amphioxus* and the *protocordates* (*tunicates*, *Balanoglossus*) the number of gills is large, occasionally reaching as many as 180 pairs in the former. In the *cyclostomes* the number varies from six to fourteen while in higher fishes the number is typically five, varying from three to seven. In land vertebrates gills are absent in the adult, but occur more or less developed in the embryo, even man himself at one stage of his existence showing indications of them, a heritage from some remote fish-like ancestor. In their disappearance have these gills left any traces behind them? There are some undoubted remnants of the gills and their associated structures, and others which can be so interpreted only with great doubt. Of the former may be mentioned the spiracle in fishes, an opening from the pharynx to the exterior just back of the head. In land vertebrates this becomes the cavity of the middle ear, which is closed externally by the tympanum and internally communicates with the pharynx by means of the Eustachian tube. The delicate ear bones, which transmit the vibrations of the tympanum to the inner ear, are probably in part derived from the first gill arch, while from the other arches develop the hyoid bone and some of the laryngeal cartilages. The blood vessels and nerves supplying the gills of the fish are also in some cases directly modified to form other nerves and vessels in the land vertebrate. If then, gill arches have been so markedly reduced in number and can be so profoundly changed as to form parts of the organs of hearing and of speech, why may they not also have been changed to form even more distant parts? Hence the origin of jaws, paired fins and fin supports or girdles have been attributed by some theorists to former gill bars, while even the lungs have been derived, according to one theory, from a pair of gill clefts.

While there is but little evidence for the latter theories, the former is not an unreasonable one. The position and arrangement of the jaws is such that they can be readily compared to a pair of gill arches united below and hinged in the middle to form the upper and lower jaws. Furthermore, the arrangement of the nerves supplying the jaws is very similar to that of those which supply the gill arches.

For the origin of the paired fins of fishes we have a more likely theory in that of the paired fin fold. The vane of the fish extends discontinuously along the median dorsal line from head to tail, and ventrally is represented by the anal or ventral fins, between tail and anus. Anterior to the anus we find the paired fins occupying varying positions in different fish. According to the paired fin fold theory the ancestral fish possessed a continuous median fin, extending dorsally

from head to tail and ventrally as far as the anus, where it divided to pass forward along the sides as a pair of folds to the head. Such a condition we actually find in *Amphioxus*, while the fossil shark *Cladoselache* possessed paired fins placed exactly as we should expect them to be had they been derived from such hypothetical fin folds. In the Japanese goldfish the anal fins, which are ordinarily single, are paired, as would happen if the paired folds extended further back than usual.

These folds are supposed to have acted as balancing organs originally, but later they became strengthened at their anterior and posterior ends while their middle parts dropped



(Above) A LUNG FISH

From Pirsson and Schuchert's *Geology*, by permission of John Wiley & Sons.

(Below) CLADOSELACHE

A fossil shark, whose paired fins give evidence of the origin of these structures from a pair of continuous fin folds. From Dean's "*Fishes, Living and Fossil*," by permission of the Macmillan Company.

out and the parts remaining were modified to form the paired fins of the modern fish.

The origin of the vertebrate limb is shrouded in the mists of the past. Whence it came, and how, we may never know; for there are as yet no links to connect the fin of the fish with the limb of the amphibians. True it is that the impress of a foot has been found in Pennsylvania in sandstone rocks of the Devonian period, when fishes were the dominant types of life; which is supposed to have been made by some lowly ancestor of the amphibians. This represents only the foot however and tells us little or nothing as to the origin of the limb as a whole. Various hypotheses have been advanced to take the place of facts, but about the most that can be said for any of them is that they are hypotheses, and one is per-

haps as good as another. The conditions of the earth and its climate under which the amphibians arose are considered in the following chapter, but their earliest history is still a blank.

One of the most difficult, but withal interesting problems of vertebrate morphology is the origin of the head. The ancestral vertebrate lacked a head. How have its descendants acquired one? This question involves in the first place one fundamental to all evolution. Is an organ developed because it is used, or is it used because it is developed? While this question has ever been a *terra incognita* in biology we know at least that form and function go hand in hand. This is the corner stone of adaptation and survival. The animal is a beautifully adjusted mechanism, in most cases built for forward movement. The anterior end is the one which first meets with changes in the animal's surroundings. Here food is taken and danger encountered. Hence the development at this end of a mouth and of special sense organs. In correlation with the development of these parts, there is a corresponding development of a brain or enlarged and specialized portion of the central nervous system, for receiving the nerves coming from the organs of special sense, and for sending out nerves controlling various parts of the body. Enlargements of the central nerve cord are not limited to the anterior end of the body. In the segmented worms and in arthropods for example there are many such enlargements or ganglia, one for each segment of the body, and when several of these segments are combined into one, as occurs in the latter group, notably in insects and crustaceans, the ganglia also fuse to form compound structures. In the vertebrates, in correspondence with the development of paired fins or limbs, there are enlargements of the spinal cord opposite the latter, which in some cases may even exceed the brain itself. Thus the enormous dinosaur *Stegosaurus* had a "brain" in the sacral region controlling the hind limbs which was larger than that in the head.

With the development of mouth, sense organs and brain there is a corresponding development of parts to enclose, protect and operate them. The development of jaws which operate the mouth has already been briefly mentioned, as have also the changes experienced by the gill arches in the land vertebrates. The most difficult questions of head development concern the brain case and especially the muscles.

The German anatomist Oken sought to solve the problem of the brain case very simply by supposing that Nature had enlarged and shaped three of the anterior vertebræ for this

purpose, but this primitive theory has long since been laid to rest. All that we know of the major part of the skull is that as the eyes, ears, nose and brain develop the surrounding tissue molds itself to fit them, forming hard parts (cartilage and bone) as a firm support and protection. But there are occasionally found some curious bones at the base of the skull or occiput which strongly suggest that the vertebræ may after all have had something to do in the building of the skull, or at least a part of it.

Of world-wide distribution, with representatives in South America, Africa, and Australia is a group of fishes known as the lungfishes, which probably represent a connecting link between fishes and Amphibia. In their cartilaginous skeleton, and in their notochord, which persists in the adult, they are very primitive types, while lungs and certain other features mark them as far advanced along the path of evolution. These fishes live in pools which dry up wholly or in part during the dry season and are filled again in times of abundant rain. Both lungs and gills appear to be used for respiration even when the pools are full of water. But when the pools begin to dry up in summer and the water becomes foul with decaying vegetation, the ability to breathe air saves the fish from suffocation. Some species during the dry season settle comfortably into the mud, retaining communication with the outer world by means of a hole in the mud, at the bottom of which they lie. Here they breathe air, resuming the gill habit when the rainy season once more replenishes their pools. In these fishes there is a "cranial rib" attached to the base of the skull somewhat resembling the true ribs of the fish and suggesting that a vertebra bearing this rib has been united with the skull.

The cyclostome skull forms but an incomplete, basket-like frame work for the brain and does not extend behind the ear, leaving the ninth and tenth nerves outside, which in higher fishes become enclosed in the skull. When we come to the land vertebrates, the reptiles, birds and mammals, this process of inclusion of nerves within the skull goes a step further and we find twelve instead of ten nerves issuing from the skull. While this process of telescoping as it were the head end of the animal is going on many of the nerves and muscles are being crowded out, while others are so modified as to bear but little resemblance to their former selves. Evidence of the loss of nerves and muscles in the evolution of the vertebrate head may be found in the presence of more numerous nerves and muscles in this region in adult cyclostomes than are found in the adults of the jawed vertebrates, and especially in the development of the latter, where a varying num-

ber of nerve and muscle rudiments appear in the embryo, which disappear in the adult.

The modifications which nerves and muscles undergo in evolution are perhaps nowhere more beautifully shown than in the evolution of the muscles and nerves of the human face. These muscles, known as the "mimetic" or mimicking muscles of higher apes and man, produce the wonderful play of expression of which the human face is capable, and through control of the lips aid very largely in speech. They are controlled by the seventh or facial nerve, which in lower animals supplies the upper neck and lower jaw. In both racial and individual development the association of muscle and nerve is very constant. Each motor nerve is, as it were, assigned the duty of controlling a certain muscle, and regardless of the wanderings of its muscle, it remains faithful to its charge, so that the best criterion for the comparison of muscles in two animals and for determining the segments to which they belong, is the nerves which supply them. So it comes to pass that when the muscles of the neck wander out over the face, or when those of the shoulder region spread themselves over the back, their nerves must needs go along with them, and we are in this way enabled to tell the original source of most of the complicated muscles of the higher vertebrates. And so when we speak or smile or frown we are using muscles, which, in some ancestor of the long forgotten past, controlled the throat and jaws and probably served it in chewing and swallowing its food.

Thus in a few words we have outlined the field of the morphologist. Perhaps some of my readers may deem the sketch one worthy of cubist art, or modern poetry. If perchance however we have gained even a glimpse of the manifold problems here involved and of some of the larger facts thus far discovered, the attempt will not have been in vain.

CHAPTER IV

The story of the rocks. Contributions of palæontology to evolution. Rise and fall of the faunas of the past.

Not alone by a comparison of the structure of living forms and their development, can we decipher the writings of evolution upon the page of time. Perhaps even more conclusive is the story of the life which is no more, of the faunas and the floras of the past. For in the record of the rocks there pass in review before us the generations of the ages telling us the story of how life has come to be. Therein we can read in a moment the tale of a million years.

Among other facts it was the existence of the extinct faunas of South America which first turned Darwin's thought into the channel of evolution. Yet in spite of its contribution to our knowledge of evolution, there are many pages missing from the record, many of which doubtless may some day be found, more probably lost forever. These "missing links" of the palæontologist have ever been a ready refuge for the dwindling forces of the opposition, attempting with broom-stick arguments to hold back the rising tide of facts. Many species of animals and plants, especially the more minute and the more primitive forms are lacking in hard parts and are not readily preserved. Some may have been destroyed in the upheavals of the earth. Still others are doubtless awaiting the pick of the geologist, which has as yet but scratched the earth's surface here and there. Thus does the palæontologist explain the gaps in his record where the story is not complete.

The student of world history written in the text book of the rocks need not trouble himself with dates, for the sequence and causes of events rather than their times are what nature strives to teach us. But the mind of curious man never is content unless speculating regarding the unknown, and so geologist, biologist and physicist have all endeavored from different data to form estimates of the age of the earth and its geological periods. Without detailing their methods it is sufficient to say that no very close agreement exists among them, the geologists claiming from 100,000,000 to 800,000,000 years since the oldest rocks were formed, the biologist asking for hundreds of millions of years for the development of life,

while the physicist is yet more extravagant, asking in the light of recent experiments on radium 1,600,000,000 years for the age of the earth since it attained its present diameter.

So in rehearsing briefly the story of the rocks perhaps we cannot do better than employ the words of the old story books and say that "once upon a time" when the waters covered most of North America and the earliest Laurentian rocks of northeastern Canada were beginning to be lifted up above the surface of the sea, life probably came upon the earth in the form of unicellular plants and animals. But regarding the birth of life the rocks are mute. We have no record of its advent or its cradle.

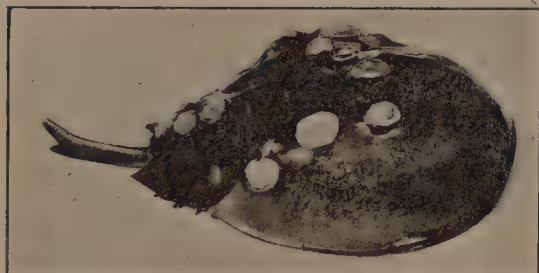
Its earliest remains known are those of the Huronian period, where buried beneath rock strata several miles in thickness are marine algæ, radiolarians and the tubes and burrows of annelid worms. Following these there appeared in the Cambrian period all the principal



A TRILOBITE

Original photograph from a specimen in the geological collection of the University of North Dakota.

Courtesy of Dr. A. G. Leonard.



A KING CRAB

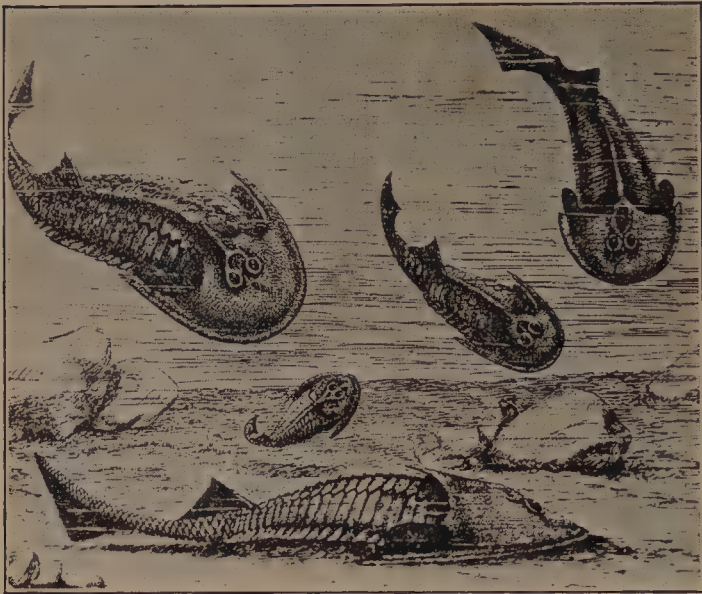
A living "fossil," related to the trilobite on the one hand, and, according to Professor Patten of Dartmouth, to the vertebrate, on the other. Photo by Elwin R. Sanborn.

Courtesy of the New York Zoological Society.

branches of invertebrate animals, with the trilobites, the curious crustacean fossils resembling the modern king crabs, and so named from the two longitudinal grooves which divide the body into three parallel lobes, occupying the dominant place. Hence this period is known as the age of trilobites. The "Ordovician" pe-

riod, which succeeded the Cambrian, witnessed the rise of land plants and corals, the marvelous nautilids, with their chambered shells, and the armored "fishes" or ostracoderms.

The latter are curious fish-like creatures whose remains have been found in several parts of this country and abroad. They had no jaws, and were abundantly protected with coats of mail, their heavy armoring of plates and spines giving them both their scientific and common names. The ostracoderms have long been a knotty problem for the palæontologists. By some they are related to the king crabs, by others to the ascidians, while yet others regard them as kin to the cyclostomes. But whatever their relationships may be they were undoubtedly highly specialized forms and have no direct bearing on the problem of vertebrate descent. They were at one time the



OSTRACODERMS

From Pirsson and Schuchert's "Geology," after Koken.

dominant forms of life in the ancient seas, for though small of size their stout coats of mail evidently served as efficient means of preservation. Their abundance is shown by the numbers of their shells, which in some places, notably in Caithness, Scotland, occur piled together in great masses, where their decaying bodies served to bind together the shell into compact masses, which today form the hard tough flagstones of this region.

The cause of this great destruction is difficult to surmise. Similar instances of the present are however by no means unknown. The Mississippi lowlands are annually converted into numerous lakes by the spring overflow from the river. Into these lakes come numerous species of fish to breed, which

when the river recedes would be destroyed in vast numbers annually, were it not for the work of the U. S. Bureau of Fisheries and other agencies, which rescue them from the receding lakes and return them to the river, or use them for stocking other waters. An instance of the destruction of fishes in this manner is cited by Lucas in his "Animals of the Past," from the observations of Mr. F. S. Webster in Texas, "Where thousands of gar pikes, trapped in a lake formed by an overflow of the Rio Grande, had been, by the drying up of this lake, penned into a pool about seventy-five feet long by twenty-five feet wide. The fish were literally packed together like sardines, layer upon layer, and a shot fired into the pool would set the entire mass in motion, the larger gars as they dashed about casting the smaller fry into the air, a score at a time. Mr. Webster estimates that there must have been not less than 700 or 800 fish in the pool, from a foot and a half up to seven feet in length, every one of which perished a little later. In addition to the fish in the pond, hundreds of those that had died previously lay about in every direction, and one can readily imagine what a fish-bed this would have made had the occurrence taken place in the past."

Devils Lake is a remnant of the glacial lake Minnewaukon, which at one time covered some hundreds of square miles in North Dakota. Due to various factors this lake is gradually drying up. Formerly pickerel abounded in it in countless numbers. Old settlers tell of catching the fish through the ice in winter with pitchforks and shipping them out by carloads. But between 1885 and 1890, coincident with a marked decrease in lake level, the fish suddenly disappeared.

In 1879 there were discovered along the edge of the Gulf Stream off the coast of Massachusetts members of a group of fishes having their home in the Gulf of Mexico, known as the tilefish. In the spring of 1882 they were found dead and dying by the million over an area estimated at from 5,000 to 7,500 square miles. This catastrophe is believed to have been due to a continuation of northerly and easterly winds which drove the cold arctic current from the north out of its usual course, overwhelming the fish with disaster. For many years no more appeared in this region, but about 1900 they reappeared and are now being taken in considerable numbers.

In the preceding chapter we have taken a glimpse at the lungfishes, which point the way from water to land inhabiting vertebrates. One would naturally expect such creatures to have a comparatively high standing in aquatic society, but strangely enough their position is a lowly one indeed. This is evidenced not alone by their structure but by their

appearance very early upon the stage of life, for the more primitive the creature the earlier its appearance in the strata of the earth. Thus we find ancient lungfishes in the Silurian, and in the Devonian, the period succeeding, they attained their greatest prominence; while the sharks, which in many respects are most primitive of the true fishes of the present, appeared at about the same time as the lungfishes, but did not attain dominance in the seas until much later.

The ancient lungfishes, like the ostracoderms, were heavily armored; some possessed powerful crushing or tearing jaws, and some may have attained a size of twenty-five feet and a gape of four feet.¹

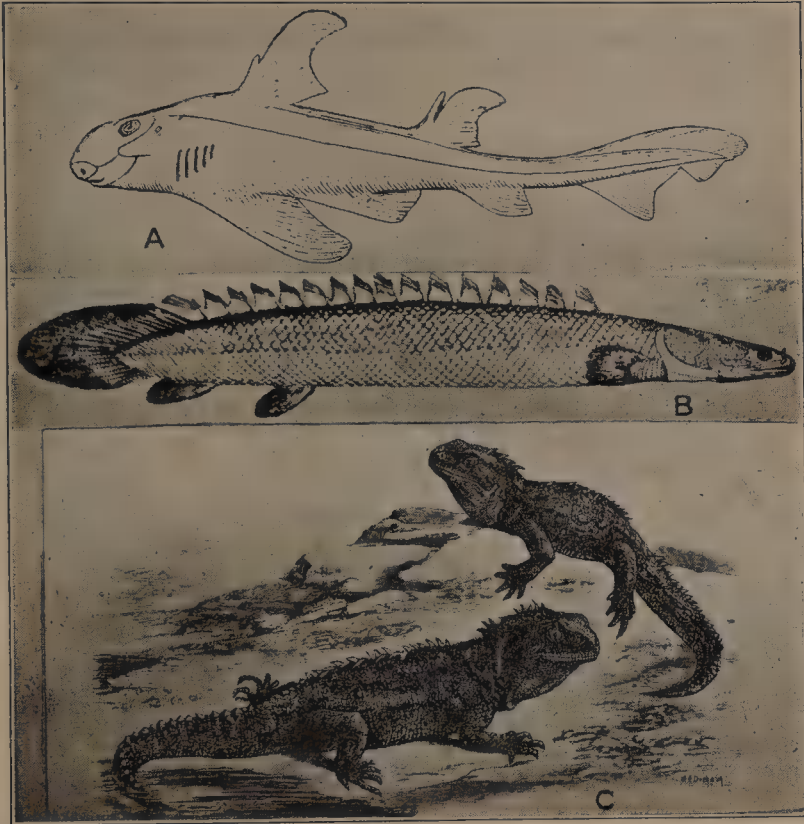
The fossil sharks include many forms of peculiar interest. One of these from the Devonian period *Cladoseleache* gives strong evidence in its paired fins for the lateral fin fold theory, as noted in the preceding chapter. The vertebræ lacked centra, resembling in this respect the cyclostomes and dipnoans. Perhaps nowhere else have fossil forms reproduced so faithfully their structure as in this shark, for Dean has shown that sections of its muscles, magnified one thousand times, showed very clearly the finer structure of the muscle substance (cross striations and sarcolemma). The modern shark is covered with teeth-like scales known as shagreen denticles, from the shagreen leather made from the skin of the shark. From these scales have arisen on the one hand teeth which are covered with enamel, and on the other scales and plates in which this is lacking. Large scales or bony plates are common in the skin of many fishes. We have already seen them in the ostracoderms and the armored fishes, but they are absent in modern sharks. In fossil forms however they were frequent and closely resembled those of the fossil lungfishes, which were probably cousin to the sharks.

The evolutionist is accustomed to thinking of life as ever changing. Yet there are some forms which have come down to us unchanged through untold ages. The shark *Cestracion* is such an one. It roamed the seas in early Mesozoic days, the dawn of the "age of reptiles," possibly 100,000,000 or more years ago.

The Australian lungfish *Neoceratodus* has persisted with but small change for an even greater length of time, while the Foraminifera, *Orbulina* and *Globigerina*, whose shells compose much of the ooze on the sea bottom, are found as far back as the Ordovician, perhaps 200,000,000 to 300,000,000 years ago, and possibly existed long before. Living on some small islands off the coast of New Zealand is the last representative

¹I am assuming here the somewhat problematical relationship of the *Arthrodira* to the *Dipnoi*.

of a decadent race of lizards, the Rhynchocephalia, whose members were among the earliest of the reptiles to appear upon the earth, and whose descendant differs but little from the ancestral types.



A. THE SHARK CESTRACION

From Pirsson and Schuchert, after Garman.

B. THE CROSSOPTERYGIAN POLYPTERUS

From Dean, "Fishes, Living and Fossil."

C. THE NEW ZEALAND LIZARD HATTERIA

From Gadow, "Amphibia and Reptiles, The Cambridge Natural History."

Band C by permission of the Macmillan Company.

Copy furnished by Conrad Lantern Slide Company, Chicago.

Other relatives of the early sharks were the Crossopterygians, whose descendants are found today in the Nile, Niger and other African rivers. In the arrangement of the dermal head plates they are suggestive of the Stegocephala or extinct amphibians which flourished in the Carboniferous or coal-

forming period, and which, from their abundance and that of the giant club mosses, is known as the "age of amphibians and lycopods."

The modern club moss is an inconspicuous humble plant, usually creeping upon the ground in the forest, and covered with small pointed leaves. It is most familiar to us in the decorations of the Christmas time. But the club mosses which we burn today as coal, were princely trees in the carboniferous



FOOTPRINT OF A PRIMITIVE AMPHIBIAN

Courtesy of Professor R. S. Lull.

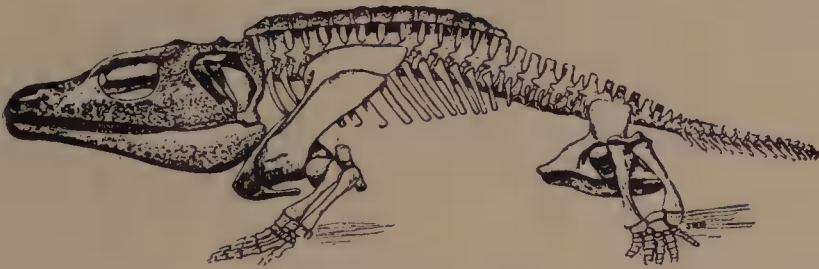
forests, one hundred feet in height and five to six feet in diameter. Associated with them along the borders of lake and pond were giant forerunners of our "horse tail ferns," slender plants, sixty to one hundred feet in height, though but one or two feet in diameter. Their descendants of the present are for the most part only a few feet in height, though a few of the South American forms may reach thirty or forty feet.

During the Carboniferous period, when the earth's surface was covered by vast swamps, wherein the decaying vegeta-

tion was forming the future beds of coal, conditions were ripe for the advent of new types of life upon the earth, and here occurred the birth of a new creation. What were the creatures that linked the fishes to the amphibians we do not know, but we have already noted indications of a change in the ancient lung fish and crossopterygian.

The earliest traces of amphibians known are some "foot-prints on the sands of time" left for our information in the sandstone of the late Devonian period by *Thinopus*, and preserved for our further instruction in the museum of Yale University, to which reference has already been made in the preceding chapter.

The creatures which marked the coming of the new race were many in number and varied in kind. Some were great in length if not in stature, measuring up to seven or eight feet, while others were minute, not exceeding a few inches in size. Some were limbed and others limbless, some had



A STEGOCEPHALAN

After Williston, "Water Reptiles of the Past and Present" (adapted from Neumayr).

By permission of the University of Chicago Press.

simple teeth, while in others the tooth was infolded from the sides producing so complex a pattern as to have given to one group the name of labyrinthodont. This character is also found in one of the crossopterygian fishes, the Devonian *Holoptychius*, a further indication of a possible relationship between them and the early amphibians. They all however possessed in common the heavy complicated coats of mail upon the head which has given the group its name of *Stegocephala*. In these early armored forms as well as in many recent ones (i. e., sturgeon and other ganoid fishes) the animal carried much of his skull, like a helmet, on the surface of his head. This was developed in the skin, while underneath was a casing for the brain developed in cartilage. In higher forms the dermal bones have sunk below the surface becoming intimately united in development with the cartilaginous brain case, the whole forming a compact structure in which in the adult it

is impossible to distinguish by structure alone the two types of bone. While the adults were terrestrial in habit they undoubtedly possessed aquatic larvæ in many cases, as is shown by the presence of gills in the fossil remains of the latter, and their kinship to aquatic forms is clearly shown by a groove in the dermal bones of the head, indicating the presence of a series of sense organs peculiar to fishes and known as the lateral line organs.

The Carboniferous period likewise witnessed a great development of many other types of animal life, spiders, scorpions,



AN IMAGINARY LANDSCAPE OF THE COAL-FORMING PERIOD

Showing stegocephalans and a giant insect in the foreground, with coal-forming plants in the background. After Williston, "Water Reptiles of the Past and Present" (adapted from Neumayr).

By permission of the University of Chicago Press.

centipedes, insects and snails, while the plants indulged in a veritable riot of luxuriant growth.

We may perhaps picture to ourselves the conditions of the evolution of land from water vertebrates in some such way as this: With the gradual recedence of the sea and elevation of the land extensive swamps were formed in which developed a luxuriant vegetation consisting of giant club mosses, "horse tail" and tree ferns and primitive representatives of our modern pines and spruces. In the dense forests bordering the stagnant pools, no touch of bright color was there to enliven the monotony of the scene, for neither bird nor butterfly

had yet appeared upon the earth. All Nature was clad in somber garb of gray and green. The air was moist and mild, with seasons same the year around. Those were indeed the "dog days" of the world. The beating wings of many giant insects filled the air, some of which, resembling our modern dragon flies, having a spread of over two feet. In the swamps the decaying vegetation was laying down the future stores of fuel.

Succeeding the warm moist climate of the early Carboniferous came the ice age of the Permian period with its change to a colder climate throughout the earth. The vast swamps gradually disappeared and in their place the Appalachian Mountains, today mere relics of their former selves, reared their vast bulk perhaps some 15,000 or 20,000 feet above the sea. With the adoption of a life on land the amphibian stem branched out, giving rise in one direction to the reptiles, in another to the modern amphibians, while yet another line led to the mammals. The earliest reptiles appeared in the Pennsylvanian or upper Carboniferous period, but not until the Mesozoic, did they attain a position of dominance.

In 1802 a Connecticut farmer named Moody ploughed up some pieces of rock bearing some small imprints, which became popularly known as the tracks of Noah's raven. Later on these tracks came to the attention of Doctor James Deane and Professor Hitchcock of Amherst College, who published extensive descriptions of them. The tracks were made mostly by three-toed beasts and were at first thought to be those of birds. But occasionally, similar tracks of four- or five-toed animals were found, and they were later shown to be those of dinosaurs, extinct reptiles, which at one time thronged the earth. These tracks appear to have been made in a long narrow estuary of the sea where we may picture to ourselves these creatures roaming over the mud flats left bare by the receding water, and leaving their impression on the mud to be hardened by the heat of the sun and preserved throughout the ages as a record of the life which was. The tracks of some 150 species of various animals (not alone dinosaurs) have been recorded by Professor Hitchcock from this old estuary, one slab alone in Amherst College Museum showing forty-eight tracks of one species of dinosaur, and six of another species. Strange to say but few remains of the makers of these tracks have been found. It is possible that most of them have been washed out to sea and destroyed, only those few left upon the shores being preserved.

But the happiest hunting ground of the dinosaurs was not the shores of the Atlantic but the borders of the lakes and rivers which occupied the present Rocky Mountain-Great

Plains area of the West. In the early Mesozoic rocks of this region are found some of the most extensive dinosaur remains throughout the world, although these are of virtually world-wide distribution. And here too has been the happy hunting ground of the palæontologist, whose labors have revealed to us the life of the long ago.

In size the dinosaurs ranged from little fellows about a foot or two long to enormous beasts, veritable Goliaths among animals. The largest of all was *Brontosaurus*, the thunder lizard, who reached a length of sixty feet, and stood fourteen feet high, with a thigh bone the height of a man. Many of them were armed with great knife-like plates and spines upon



DINOSAUR TRACKS

Courtesy of the American Museum of Natural History.

the back and tail. Among these were the stegosaurs or armored lizards, the largest of whose plates were two feet in height and length, while near the end of the powerful tail, eight or ten feet long, projected two pairs of vicious spines nearly three feet long. The three-horned dinosaur, *Triceratops*, who some millions of years ago inhabited what are now the plains of the Dakotas, Wyoming, Montana and Colorado, bore a horn over either eye and one on his snout, like the horn of a rhinoceros, and a great fringed shield upon his neck; while many another was equipped with armor more bizarre perhaps than practical in the battle of life. Many however were naked, so that as a protective adaptation these various plates and spines seem to have had but doubtful value.

Some of the dinosaurs browsed on the abundant vegetation of lake and river shore, while others were eaters of flesh and may have preyed upon their weaker brethren or fed upon their decaying carcasses.

Unfortunately for the dinosaur and *vice versa* for their prey and their enemies, if they had any, their brains did not keep pace with their brawn. *Thespesius*, who was twenty-five feet long and a dozen high, had a brain weighing less than a pound, while *Triceratops*, who probably tipped the scales at something over two tons, did not possess over two pounds of gray matter. Some indeed had more nerve in their hind quar-



BRONTOSAURUS, THE "THUNDER-LIZARD"

From a restoration by Chas. R. Knight.

Courtesy of the American Museum of Natural History.

ters than in their head; in *Stegosaurus*, the sacral enlargement of the spinal cord, which controlled the powerful hind legs, being twenty times as large as the brain. Corresponding with their paucity in brain substance the intelligence of these creatures must have been low indeed, and this, together with the vast bulk of many of them, may have contributed to their extinction.

But the dinosaurs were not the only members of the reptile tribe which dominated the world in Mesozoic days. There were reptilian aeroplanes and submarines as well. In the great Cretaceous sea which divided North America into eastern and western continents, covering the fertile plains and



STEGOSAURUS

From a restoration by Chas. R. Knight.

Courtesy of the American Museum of Natural History.



TRICERATOPS

A former inhabitant of our western plains. From Lucas, "Animals of the Past."

Courtesy of the U. S. National Museum.

arid plateaus which lie between the Mississippi River and the Rocky Mountains, were swarms of giant lizard-like reptiles known as mososaurs, whose remains have been unearthed by thousands in the chalk bluffs of western Kansas.

While the mososaur was playing the rôle of Neptune in the Cretaceous sea, some of his relatives took to flying and as pterodactyls or flying lizards competed with the first of the birds for the mastery of the air. The old classification of beasts that fly and beasts that swim and beasts that walk was about as logical as that of the small boy who divided people into men, women and college professors, for many different animals have aspired to fly and most of them



RHAMPHORHYNCHUS, A WINGED REPTILE

From Neumeyer after Zittel.

have met with eminent success. The success of the reptile at aviation was but short-lived however speaking in terms of biological time, for the pterodactyls soon joined their cousins the dinosaurs, the mososaurs and most of the other antique saurians, and sank to a watery, which later became a rocky, grave, to be resurrected after untold ages by the prying eye and patient pick of the palæontologist. The pterodactyls had wings of a thin skin or membrane stretched between fore and hind limbs somewhat like the wings of a bat. In the pterodactyls however only one of the fingers was lengthened as a support for the membrane.

While the pterodactyls could not compete with the dinosaurs or mososaurs in respect to size, nevertheless one at least

attained fairly respectable dimensions, Pteranodon having a wing spread of twenty to twenty-five feet. This creature with its long arms outstretched, a slender body and narrow neck, at the top of which was poised a long narrow head, about half of which was beak, might well have served as a model for some Egyptian or Assyrian god or goddess. Rhamphorhynchus, on the other hand, with his long tail, semi-human form and claw-like fingers, would have made a very good model for a winged Satan.

While the pterodactyls are not directly related to birds, they nevertheless show certain distinctly avian features, one of the most notable of which is the hollow bones. In birds air sacs extend from the lungs throughout the body even into the bones, while the lungs themselves are small, but richly supplied with blood vessels. These air sacs serve as reservoirs for air, somewhat after the manner of a rubber bulb on a pipette, serving to force strong currents in and out of the body through the lungs, and thereby gain efficient aeration for the blood; which in birds is kept at a high temperature by the active oxidation which takes place in the body in correspondence with their great activity. Not only do these spaces in the bones serve as air reservoirs, but they also serve to lighten the bones, increasing their size, relative strength, and surface for attachment for muscles, without unduly increasing their weight; just as the greatest strength in a pillar for a given amount of material is obtained by making the pillar hollow.

While we know very little about the lungs in the pterodactyls it is interesting to find precisely the same adaptation for lightness and strength of bone as we find in the birds. This suggests Lamarck's idea that use (flight) produces change (lightness of bone) in flying reptile as in flying bird. But let us not be too hasty in swallowing alluring hypotheses. We find to a certain extent the same air spaces in the bones of the crocodile, which has never had any aspirations for flying, while the lizard, which is also in the main satisfied with a mundane existence, has small air spaces or reservoirs attached to its lungs. Thus we are driven to the conclusion that the pterodactyl and the bird have made use of their opportunities and have learned to fly because they "were built that way," while the opportunities for flight of the lizard and the crocodile are too small for them to use.

But there are yet other points of resemblance between bird and pterodactyl. In birds of flight the sternum or breast bone has a prominent ridge or keel like a boat, which has given them the title of *Carinatae* or keeled. This keel furnishes an additional surface for the attachment of the powerful wing muscles. So too the pterodactyl had a keeled ster-

num. The pterodactyl's skull is prolonged into a prominent beak like that of a bird, while in some instances its teeth are as scarce as those of the proverbial hen. Yet others possessed numerous strong, sharp teeth lodged in sockets in the jaw. The cavity of the skull bears a great similarity to that of birds, while the sutures or lines of union of the skull bones, as in the bird, have largely disappeared. The zoologist believes this to be a case of "parallel evolution." The pterodactyl had dreams of becoming a bird, but never quite achieved his ambition.

But if the attempt at aviation by the true reptile was short-lived, he yet produced the greatest aviators among animals—the birds.

In the famous Solenhofen quarries in Germany there was discovered on August 15, 1861, the print of a single feather, and a few weeks later the impression of the bird itself was discovered. Archæopteryx, the primitive or ancient bird, as his name signifies, was indeed primitive, but was distinctly a bird, for he wore feathers, a distinction possessed by none of his reptilian ancestors that



RESTORATION OF ARCHÆOPTERYX

From Lucas, "Animals of the Past."

Copy furnished by Conrad Lantern Slide Company, Chicago.

we now know. And yet the improbability of a bird hatching full-fledged out of a reptile's egg, as St. Hilaire suggested, is so unlikely, that we must assume many intermediate stages in avian development; stages, which Mother Earth has as yet declined to reveal. While Archæopteryx is a full-fledged bird so far as its feathers are concerned, it shows its reptilian parentage in several ways. The modern bird possesses only a few small vertebræ in lieu of a fully formed tail, from which the tail feathers radiate fan-like; Archæopteryx however had a long reptilian tail, with numerous vertebræ, and the feathers arranged in a row on either side. It still had a full set of teeth like the other early birds, Hesperornis and Ichthyornis, which were discovered by Professor Marsh in 1870 in the chalk beds of

western Kansas, which were once at the bottom of the old Cretaceous Sea. Traces of teeth still occur in the embryos of some birds of the present, a heritage from some ancestor of the distant past. While *Icthyornis* still had teeth, it had progressed much further along the path of avian development than *Archæopteryx* in the structure of the hand. Nature in her experiments is prodigal in the production of variations, most of which she will never use in the development of new species; but once she is on the track of a useful variation she becomes a strict conservationist and wastes no energy in the



HESPERORNIS

An extinct diving bird with teeth, an inhabitant of the great Cretaceous sea which once covered our Great Plains. From Lucas, "Animals of the Past."

Courtesy of the U. S. National Museum.

maintenance of useless parts. So in the hand of the modern bird and in *Icthyornis* as well, we find one of the fingers being greatly strengthened for the support of the wing feathers, and the others correspondingly reduced. The typical reptile has five fingers, which in the modern bird are reduced to one plus two rudiments, while *Archæopteryx* had dropped only two of his digits and still remained in possession of the claws on his wings which the modern bird has dispensed with as entirely out of date. There is however one conservative member of the class who still retains a reminder of his reptilian past in the form of a claw at the angle of the wing,

Apteryx, or the kiwi of New Zealand, a country which in its fauna is a sort of old curiosity shop, retaining such relics of the past as the Port Jackson shark, the tuatara, the kiwi and until recently the moas. Yet a further legacy from his reptilian ancestry did *Archæopteryx* possess. This is a set of abdominal ribs, or rib-like bones in the ventral wall of the abdomen, which he shared in common with the New Zealand lizard and the crocodile.

As to how birds took to flying we of course have no certain knowledge. But we have some very ingenious and interesting theories. In the first place what was the probable origin of the feathers? A feather consists of a central shaft or quill from which extend two rows of branches or barbs, and these



PART OF A FEATHER

Showing shaft, barbs, barbules and hooks. Original.

in turn give rise to a series of little barbs or barbules which interlock with one another by means of rows of small hooks; the whole forming a firm resistant membrane serving as a propeller in the case of the wing feather, a rudder in that of the tail feathers, and a protective and insulating covering for the general body surface. At the base of the quill is a small papilla or projection of the dermis, or lower layer of the skin, which carries nerves and blood vessels and serves to nourish the growing feather. The feather itself arises as a tube of modified horny cells derived from the epidermis, or outer skin layer, which splits into several parts in development, which spread out to form the barbs and barbules. This

applies to the ordinary or "contour" feather. The "down" and "hair" feathers differ in development, although all have essentially the same structure. Hairs are also developed fundamentally in the same way as the feathers, with a dermal papilla, or core, at the base and a horny shaft, which however is solid and not hollow as in the feather.

Both of these structures, being derived from the horny layer of the skin, are believed to be modifications of the horny reptilian scale, which in its turn probably owes its origin to the epidermal layer or enamel of the placoid scale of the shark, from which also has evolved the enamel of the mammalian tooth.

But to return to the original question of the origin of the birds. The theory of the Hungarian palæontologist, Nopsca, supposes the bird to have arisen from a long-legged, long-tailed, short-armed running reptile, which as it ran flopped its arms to aid its motion, on somewhat the same principle that a man uses his arms in a race. If some of the scales along the posterior angle of the arm and along either side of the tail were to enlarge, they might readily aid the forerunner of the bird in its motion and by further enlargement and modification give rise to feathers, and the arm become a wing, and the reptile a bird.

Another theory, advocated by Osborn, and more recently by Beebe, assumes an arboreal reptile as the ancestral bird. This creature is supposed to have been gifted with four wings instead of two and a long tail, which it used much as a flying squirrel uses its tail in sailing from tree to tree. With loss of the hind pair of wings and strengthening and improvement of the front pair, the sailing reptile became a flying bird. In support of this theory Beebe adduces a very interesting fact. He points out that in the newly hatched bird there is a row of quills running along the outer side of the leg, in such a position that, if developed, they would produce a miniature wing. And further, just as in the case of the secondaries, (the smaller of the flight feathers in a bird's wing) there develops above these quills and alternating with them a second row of quills, which if developed would produce covert feathers. Similar tufts of feathers occurred in Archaeopteryx, which is strong evidence for Beebe's theory, for as we have already seen, higher animals tend to repeat in an abbreviated way the structure of their ancestors. Yet others adopt a compromise theory and assume that while Archaeopteryx lived in trees, using his wings as well as his feet for grasping the branches, yet his flight was not merely a sailing one, but that the wings were actively used for this purpose.

But whatever may have been the development of feathers and origin of flight in birds we find in *Archæopteryx* one of the best "links" between two great groups anywhere to be found in the animal kingdom.

While *Archæopteryx* was smaller than a crow many of his extinct relatives maintained the reputation of their reptilian connections for size. Among these are the moas of New Zealand, which must have become extinct within the memory of man, for less than a century ago the Maoris firmly believed in their existence. Their largest representative was the giant moa, *Dinornis maximus*, which was at least ten feet high. Another giant of the bird world was *Æpyornis* of Madagascar, legends of which may have served as the basis for the roc in the tales of Sinbad the Sailor; but this was equalled by *Phororachis*, the giant of the Patagonian pampas, who flourished in Miocene days, long before the advent of man, and who was seven or eight feet in height and had a skull larger than that of a horse. Another although smaller bird was the vulture, whose remains have recently been unearthed or rather untarred from the tar pits of Rancho La Brea near Los Angeles, Cal., whose spread of wing was probably greater than that of the great condor, which today circles about the Andean peaks of South America.

And so for the present we may leave the extinct reptiles and their feathered kin, who in days of yore ruled earth and sea and sky. "For the wind passeth over it and it is gone and the place thereof shall know it no more." So passed these creatures of antiquity, to give place to races better fitted to cope with the new environments of the passing ages and the changing earth. Many if not all of them will in their turn go down in life's struggle before the advancing armies of future generations, these in turn giving place to others, until life itself shall be no more.

The reptiles and the birds form one of the topmost branches of the vertebrate tree, while the mammals form the other. The latter, while less spectacular in their evolution than the former, are of even greater interest since man himself is one of them, and since they are the latest, and in many ways dominant group among the vertebrates of today.

As in the case of all great groups of animals and plants the actual ancestor of the mammals is unknown. Nor is it certain whether they are the offspring of amphibian, reptile or some intermediate stock. Their first appearance was near the beginning of the Mesozoic era, when the reptilian dynasty was arising to rule the earth. The first of the mammals were small creatures and were probably the prey of the carnivorous reptiles, although they in turn may have been one cause of

the extinction of many of the latter, by destroying their eggs with sharp gnawing teeth which well served them for this purpose.

Although the origin of mammals is uncertain we find a possible source in a group of reptiles known as cynodonts from the dog-like character of their teeth, which occur in triassic rocks in South Africa. The skull in many respects resembles that of a mammal, while in others it shows reptilian characters.

But the cynodonts are found in the Trias, at the very beginning of the Mesozoic era, at a time when the great reptilian tree was but a slender sapling, while the "age of mammals" does not commence until the close of the Mesozoic era many millions of years later. What happened then to retard mammalian development during the æons of time in which "great oceans waxed and waned and tiny hills to mountains grew"? It is possible that during all this time our ancestors were living, like the Israelites of old, in bondage to the Pharaohs, who in this instance were represented by the carnivorous reptiles; but when the "first born" of the reptiles were cut down and the reptilian stock smitten by the inexorable hand of time, then the mammals arose, to take their "place in the sun" and become the "lords of creation." Or perchance the available food supply was not abundant at the time of their birth and thus their development was checked until a more favorable season.

"Perhaps the most remarkable thing which the history of the Mesozoic brings forth is the immense period of evolutionary stagnation on the part of the mammals. They are first actually recorded in the Upper Triassic rocks of three rather remote localities, North Carolina, Germany, and South Africa, and are already differentiated in dietary habits. During the Mesozoic, they develop in numbers and to a certain extent in tooth specialization. They do not, however, increase markedly in size, but are humble folk, so far as our records have revealed them, until the extinction of the dinosaurs has been accomplished. One cannot but associate the idea of mammalian suppression with that of dinosaurian dominance in the relation of cause and effect, unless it shall some day be revealed that the mammals were undergoing a marked evolution beyond the temperature-limited habitat of the reptiles. That the former showed no marked evolutionary advance in the place where the dinosaurs actually occurred is an attested fact, and the significance of the dinosaurian check is no more graphically shown than by two specimens in the Yale Museum. . . . The figure here reproduced is from a simultaneous photograph of these two speci-

mens, which are therefore on exactly the same scale. The single dinosaurian tooth greatly exceeds not only the tooth of the mammal, but the containing jaw or even the entire creature as the imagination conjures it up."²

As to the cause of mammalian development we can again only conjecture. Lull has suggested that increasing dryness of climate and corresponding desert conditions, necessitating speed on the part of animals in search of food and water, or in flight from their enemies, coupled with the extensive glaciation in the Southern hemisphere in late Palæozoic times,



TOOTH OF A DINOSAUR COMPARED WITH THE JAW OF A CONTEMPORARY MAMMAL

From Lull's "*Organic Evolution*."

Courtesy of Professor Lull and the Macmillan Company.

which glaciation would mean increasing cold and the need of a furry covering, were the inciting causes. But apart from the fact that this explanation implies, if it does not state, an acceptance of Lamarck's doctrine, which at the present time is in the discard with most zoölogists, is the further fact that the succeeding or Mesozoic era was one which witnessed the remarkable development of reptiles, which are distinctly types not adapted to aridity and coldness of climate. Perhaps the best we can do after all, when, as so frequently happens in philosophy and science, we find

² Lull, "*Evolution of the Earth*," pp. 133-134. By permission of the Yale University Press.

ourselves "up a stump," is to accept the philosophy of Topsy and admit that they "jest grew."

The Mesozoic and early Eocene mammals were all primitive types and most of them disappeared from the face of the earth without leaving any descendants.

"It is the mammals which were the strangest element of Paleocene life, and (an) imaginary observer would find no creature that he had ever seen before. The difference from modern mammalian life was not merely one of species, genera or even families, but of orders, for only one, or at most two,



THE OPOSSUM

The only marsupial at present found in the United States.

Photo by Elwin R. Sanborn.

By permission of the New York Zoölogical Society.

of the orders now living were then to be found in North America, and both of these (marsupials and insectivores) were primitive and archaic groups, which seem like belated survivals in the modern world."³

It is possible however that the marsupial types of these early mammals have come down to us as the marsupials of the present. The marsupials derive their name from the marsupium or pouch in which they carry the young for some time after birth. These latter are born in a very undeveloped condition and at birth are transferred by the mother

³ Scott, "History of Land Mammals in the Western Hemisphere," p. 284. By permission of the Macmillan Company.

to her pouch where their mouths become temporarily attached to the mother's teats and where they grow in safety until ready for their second *début* in the world. Well-known examples are our own opossum, and the Australian kangaroo. The distribution of modern marsupials is very peculiar and with other facts has given rise to interesting speculations regarding the earlier form of Mother Earth. Their representatives are found today exclusively in Australia and adjacent regions, South America and tropical North America, with the exception of the opossum of the United States. In



THE SPINY ANT-EATER

A monotreme, one of the most primitive of mammals.

Photo by Elwin R. Sanborn

By permission of the New York Zoological Society.

Mesozoic and Eocene time however the marsupial stock was distributed over North America and Europe and possibly Asia as well.

The distribution of the ostrich in Africa and its relatives, the rhea in South America, and cassowary and emu in Australia and the East Indies and the recently extinct moa of New Zealand, is similar to that of the marsupials. These facts and other similar ones have led many biologists and palæontologists to the belief in a migration of life from the northern hemisphere into the southern at some very early period in the earth's history. They have also suggested the existence of former land connections between South Amer-

ica, Africa, India and Australia known as Antarctica and Gondwana Land which is supposed to account for the similarity of many of the forms of life in the two regions, not only of birds and mammals but of reptiles, amphibia, fishes, invertebrates and plants as well.

While the early mammals disappeared for the most part without issue there were among them some which were elected to serve as progenitors of the mighty tribe which has since peopled the earth. Whence came the present monotremes and marsupials is matter of much doubt, their relationship to the primitive members of these groups being uncertain, but the origin of modern carnivores is pretty certainly to be found in the ancient creodonts.

After the close of the Cretaceous period with the rise of the western part of the North American continent and consequent draining of the great inland sea, which formerly stretched from the Arctic Ocean to the Gulf of Mexico, there appeared extensive swamps or fresh water lakes in what is now North Dakota, Montana and the Rocky Mountain and Great Basin regions and British Columbia. These various lakes did not all appear at once, but succeeded one another with succeeding changes in elevation and form of the land. It was now that the lignite beds of North Dakota and Montana were laid down, covering an area approximately 60,000 square miles in extent.

"The climate, as shown by the plants, was much milder and more uniform than that of the Recent epoch, though some indication of climatic zones may already be noted. The vegetation was essentially modern in character; nearly all our modern types of forest-trees, such as willows, poplars, sycamores, oaks, elms, maples, walnuts and many others, were abundantly represented in the vast forests which would seem to have covered nearly the entire continent from ocean to ocean and extended north into Alaska and Greenland, where no such vegetation is possible under present conditions. Numerous conifers were mingled with the deciduous trees, but we do not find exclusively coniferous forests. Palms, though not extending into Greenland, flourished magnificently far to the north of their present range. On the other hand, the Paleocene flora of England points to a merely temperate climate, while that of the succeeding Eocene was subtropical." "

Upon the land and in the lakes were laid down deposits of wind-driven dust or loess and volcanic ash or tufa, while the streams deposited in their deltas sand and gravel carried down from the higher lands in which they took their rise. The majestic Rocky Mountains of today were then in their

*Scott, locus citatus, pp. 102-103.



Top—RESTORATION OF UINTATHERIUM

Center—RESTORATION OF CORYPHODON

Bottom—RESTORATION OF THE CREODONT DROMOCYON

From drawings by Horsfall in Scott's "Mammals of the Western Hemisphere."

By permission of the Macmillan Company.

Copy furnished by Conrad Lantern Slide Company, Chicago.

infancy, and great was the travail of the earth in bringing them forth, for several active volcanoes marked their course. From these, great clouds of ashes were hurled forth to settle upon earth and water. Such was the home of the creodonts, the forerunners of modern Carnivora. Of these the Miacidæ are believed to represent the progressive branch destined to flourish and bring forth fruit, while the other branches have withered and died. They were creatures much like the modern carnivores in general appearance, but with small brain-case and a very high ridge on the upper side of the skull for attachment of the powerful jaw muscles, and the teeth were not so well formed for eating flesh as in modern carnivores. Remains of the Miacidæ have been found from Wyoming to New Mexico. As in many another case of evolution in animals, the old adage "great oaks from little acorns grow" applied to the Miacidæ, for the forerunners of the "king of beasts" and the man-eating tiger were little fellows content to prey on smaller fry of field and forest. Many of their relatives however were larger fellows, equalling in size a small bear. Associated with the creodonts were other creatures, many of them of huge size and ungainly form. Here shambled the coryphodonts, ugly brutes, equalling a small rhinoceros in size and somewhat resembling a hippopotamus in form, with heavy tusks, elephantine feet and short, heavy legs, and Uintatherium, a creature so bizarre in form that it seems as if Nature had designed it to grace a palæontological dime museum. The skull of this beast, not being able to find room for growth along ordinary lines, ran riot in the matter of horns. He had horns on his snout and horns on his forehead and horns at the back of his head and as if these were not enough to gratify his propensity for horny embellishment, his upper canine teeth were prolonged into great tusks, or horns turned upside down. The female however was much more conservative in the matter of horns, while she lacked the tusks entirely. The general form of the beast was quite similar to that of its relatives, the coryphodonts. Beside these ungainly beasts there were others resembling the present sloths of South America and representatives of the modern shrews and moles.

As in the case of man the aborigine has given place to the invader from distant lands, so too the primitive mammals of North America, which were natives of the country, have been displaced by more recent types which have immigrated from other regions. Whence they came cannot certainly be determined, but probably Asia was their birthplace, whence like the human race they have wandered throughout the world. It has repeatedly happened in geologic history that

North America has been connected with Asia by a mass of land or "bridge" across Behring Sea. It appears likely that there was a similar "bridge" joining America and Europe at this time (Lower Eocene), for many mammals were common to both continents.

The cause of their migration is likewise uncertain, but natural increase and competition for food may have been one of the compelling causes then as they are now in determining animal movements. We need only recall the movements of the herds of bison, which formerly roamed across



EOHIPPIUS, THE "DAWN HORSE"

From a restoration by Chas. R. Knight.

Courtesy of the American Museum of Natural History.

our western prairies in search of food, the plague of locusts which overwhelmed the early settlers in Kansas, or the spread of the English sparrow from east to west to find an explanation for animal movements in the past. But possibly another, and even more potent factor was the gradually increasing refrigeration of the polar region, which occurred subsequent to the Eocene, and which culminated in the glaciation of the "great ice age" of the Pleistocene epoch. In the latter there is abundant evidence of the movement of northern mammals before the advancing ice, for we find remains of walruses in New Jersey, of reindeer in southern France and of the musk ox in Kentucky.

Among these immigrants of the past were members of the rodent or rat order, tiny forerunners of the artiodactyls or mammals with paired toes, including cattle, sheep, camels, goats, pigs, etc., ancient tapirs, and Eohippus, the first of the horses, a graceful little creature about the size of a domestic cat, with four front, and three hind toes and indications of a fifth toe in the front, and possibly two extra toes in the hind foot. In the Wasatch beds which cover large areas in New Mexico, Colorado, Utah, Wyoming and Montana their remains are found in great numbers, so that they must have been common inhabitants of this region in early Eocene days.



THE TARSIER

Whose relatives in days gone by inhabited the forests of North America, but today is found in the East Indies and the Philippines. From Lull, after Brehm.

But perhaps the most interesting of the early invaders of North America were small monkey-like habitués of the tree-tops in the Wasatch forests. Their invasion however was but temporary, as they died out later in the Eocene, never to reappear in North America. Inhabiting the forests of the Malay Archipelago is a little squirrel-like monkey, the tarsier. "The particular interest which *Tarsius* possesses for the student of American mammals is its resemblance to the Wasatch genus *Anaptomorphus*, the type of a family which was abundant and varied in the lower and middle Eocene. This genus was remarkably advanced in view of its great antiquity. . . . The face was very much shortened; the orbits were very large and encircled in bone, but without the pos-

terior wall. This produces a decided likeness to the Tarsier and is no doubt indicative of nocturnal habits. The cranium was remarkably large, and no other Wasatch animal had a brain-case so capacious in proportion to its size. . . . It is hardly likely that these American lemurs were the actual ancestors of the anthropoids, but they closely represent what those ancestors must have been.”⁵

With the passing of the Eocene epoch the early mammals vanished from the face of the earth. The cause of their extinction is as uncertain as is that of the disappearance of the great reptiles. Undoubtedly the broad underlying factor was lack of adaptability to new conditions, both physical and biological. With changes in climate and in the form of the earth's surface (rise of mountains, formation of seas and lakes, islands and archipelagoes forming out of continents, etc.) new environments develop and animals which cannot meet these new conditions are bound to perish. Physical changes also produce new conditions of food and these in turn lead to new competitions among animals themselves. Osborn believes that three of the main factors in the extinction of the ancient mammals were their small brains, their deficient teeth and poor feet, all of which are serious handicaps today in human evolution. Marsh has shown that surviving races of animals have in general larger brains than dying ones, and while it is not a hard and fast rule that the larger the brain the greater is the intelligence, still brain power and brain size do in general go hand in hand, and these in turn are good indices of success, or survival in the struggle for existence.

From the northern invaders have come then in great part the mammals of today. In a brief review such as the present, space does not permit a consideration of any but a few of many interesting forms whose remains have been made known to us by the labors of the palæontologist. But we may catch a fleeting glimpse in passing of some of the creatures of the past which once roamed upon our hills and dwelt within our valleys.

One of the most picturesque of these was *Smilodon* or the saber-toothed tiger, which stalked his prey over the western continent from Pennsylvania to Argentina, during the Pleistocene epoch, when the polar ice cap successively invaded and retreated over northern North America. This powerful and ferocious beast was the size of the present tiger, with shorter, stouter legs than those of modern cats, a heavy body, powerfully muscled, and a short tail as in the modern bobcat. But the most striking feature were the tusks in the

⁵ Scott, *locus citatus*, p. 581.

upper jaw which are eight inches long or more. These tusks have somewhat the shape of a scimitar, being flattened on the sides and narrow transversely, with a saw-tooth edge behind. The opposing teeth of the lower jaw were undeveloped. How the animal could have handled these enormous tusks is a problem, but it has been suggested that they were used somewhat as a venomous snake uses its fangs, to strike and kill the prey rather than for cutting and biting it. This theory is supported by the relatively weak lower jaw, as compared with that of a modern cat, and the large mastoid process at the base of the skull, in which were inserted the great mus-



THE SABER-TOOTHED TIGER

From a restoration by Chas. R. Knight.

Courtesy of the American Museum of Natural History.

cles used for lowering the head and striking the prey. The gape must have been enormous to allow free play for the use of these great fangs, and indeed it is not impossible that the animal owes its extinction to overgrowth of these teeth, which finally became a hindrance rather than a help to their possessor.

And what were the victims of this cruel tyrant of the past? Its occurrence with the thick-skinned cumbrous beasts like the elephant and the giant sloth, and the fact that it must have been less agile than its modern cousins, to judge from its thick-set legs and body, have been advanced by Lull as reasons for supposing that these animals formed its principal prey; while the swifter footed, more agile cats of to-

day, like the lion and tiger, are adapted to preying upon swift-footed beasts such as deer or horses.

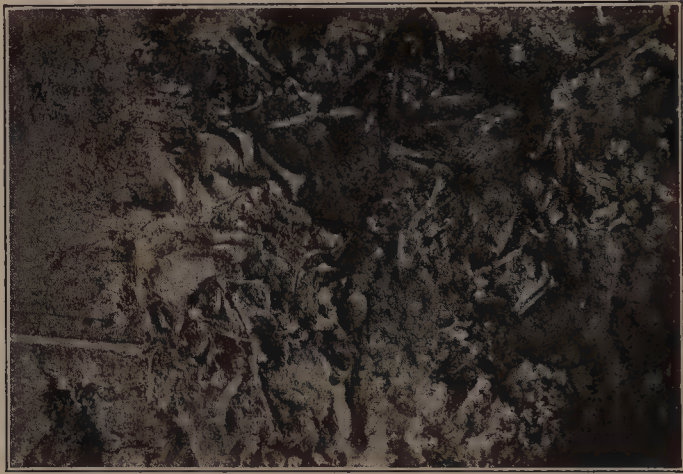
In the oil fields of southern California there was recently discovered one of the most remarkable "finds" of bones ever made in America, and the Rancho La Brea beds are now famous the world over. About fifteen feet below the surface of the ground is a layer of oil-bearing rock, from which oil and tar issue and evaporating and oxidizing form beds of asphalt. These tar pools are intermingled with pools of water at many points, and many of them are partly covered with water. In these tar pools animals are occasionally trapped, several species of wild animals having recently come to an untimely end in this manner, while domestic animals are frequently caught and liberated only with great difficulty. Professor Merriam of the University of California who has studied these pools more extensively than anyone else, cites the following amusing incident of the efficacy of the tar as a trap for animals. "A number of workmen were engaged in covering a piece of road with asphalt, and had left their work only partially completed in the latter part of a warm afternoon. A drunken man passing a short time afterward fell by the roadside and remained there to take a nap. By chance he extended himself on some of the partly softened asphalt. Falling asleep quickly he evidently lay for a long time without moving. During this time his body sank part way into the sticky mass. After the sun went down and the atmosphere had cooled, the tar hardened somewhat, and by morning it was practically solid. When the man awoke, he found it impossible to extricate himself. His cries attracted a number of persons, who attempted to free him. Unfortunately the whole side of his body and his head were firmly set in the asphalt, and it was very difficult to give him any assistance. With the aid of an axe and various other tools, they finally succeeded in cutting and prying him out, but not without injuring him somewhat. He was taken to a hospital nearby, where numerous attempts were made to separate the tar from his body. Only after shaving his head and scrubbing him with benzine was it possible to give him an aspect of respectability."*

The presence of bones in these tar pits has been known for a half-century, but until recently they were generally assumed to be the remains of modern animals and but little attention was paid to them. About twenty years ago however they came to the notice of Professor Merriam, and since then have been excavated, and carefully studied and described. The pits are filled with a heterogeneous collection

* "*Harper's Weekly*," Dec. 18, 1909.

of bones, great and small, saber-toothed tigers and giant wolves, imperial elephants, camels, bison, horses and ground sloths mingling their remains with those of mice, rabbits and squirrels. Many of these bones are those of modern animals, but a large number represent extinct forms. Of bird remains the most striking are those of the giant condor, but even more interesting are those of a peacock, an immigrant from Asia, and unknown elsewhere in America.

The frontispiece to Scott's beautiful work on the mammals of the western hemisphere is a drawing by Horsfall representing one of these tar pools of southern California in Pleistocene time, which is of fascinating interest, especially to one who has seen these wonderful collections of prehistoric,



EXCAVATION OF A TAR PIT AT RANCHO LA BREA NEAR LOS ANGELES, CALIFORNIA. Original.

mingled with modern life. Mixed in the tar at the edge of the pool lies the carcass of a giant elephant, over which a giant wolf and a saber-toothed tiger are quarrelling for possession, while another wolf caught in the tar nearby snarls defiance at the others. In the background, perched on a dead tree, or soaring overhead, are expectant condors, waiting to feast upon vanquished and victor, when they like their prey shall have fallen victims to the relentless tar, while on the shore are the bleaching bones of some former visitant to the fateful pool. And thus may we picture to ourselves the tragic fate of creatures whose remains have come down to us today to tell the story of the life that was.

Here too are found the bones of camels which once inhabited North America, and migrated thence to the old world probably via the Behring Isthmus, which at various times

formed the route of migration of many forms between the old world and the new. Why the camels should have left their birthplace in North America and wandered forth to the ends of the earth is a mystery, as are so many other problems in the history of animals as well as in that of man. So too the horse, whose earliest home is uncertain, underwent his great evolutionary development in North America, whence he migrated from time to time into South America, Europe, Asia, and Africa, and finally disappeared from his ancestral home, only to be re-established there by the agency of man.



EARLY DAYS IN THE TAR POOLS OF SOUTHERN CALIFORNIA

A saber toothed tiger and giant wolf contesting the carcass of an elephant while condors are waiting nearby, until victor and vanquished alike shall have fallen victims to the tar. From an illustration by Horsfall in Scott's "History of Land Mammals in the Western Hemisphere."

By permission of the Macmillan Company.

Here we encounter another unsolved problem in palæontology—the extinction of the horse in the Americas. Glacial conditions alone would seem inadequate, nor does there seem to have been a sufficient development of larger carnivores to explain it. So some sort of a pestilence has been called in to aid in the explanation, but this is merely a recourse to the unknown, a last stand of the defeated philosopher, when no available facts will serve his purpose.

Thus in the "sands of time" as well as in flesh and bone

and sinew of living creatures may we trace the ways of evolution, whose workings "declare the glory of God." Many indeed are the blank pages in the record, which must be left for the future to fill in; but in spite of all the gaps the voices of rock and flower, of the "bird of the air" and the "beast of the field" tell the same story—a tale of attempt and achievement, of progress and of promise for the days which are to be.

CHAPTER V

Geographical distribution of plants and animals. Relation between organism and environment. Methods of, and barriers to the spread of plants and animals. Plant and animal societies. Life zones of North America.

In surveying the organic world today one is struck by the fact that the lower organisms as well as man are distributed in societies, each of which has its characteristic aspect. From the wind-swept tundras of the north to the sunlit everglades of the south, we may pass in review one succession after another of plant and animal societies, each more or less distinctive of the region in which it occurs; and if we encompass the earth from east to west we encounter an even greater diversity of living things, even though the physical characters of every realm are more or less alike. And further, if we survey the past history of life upon the earth, we find an ever-shifting panorama, as fascinating in its changing scenes as is the restless sea of human life, whose ebb and flow make history. And what the cause of all this change? Where may we find a key to the checker-board puzzle of the living world? How have arisen the organic societies of past and present, and why their ceaseless succession like the play of light and shade? While the immediate causes of the movement and association of plants and animals upon the earth is as yet in many instances obscure, we may seek for the ultimate cause in the great principle of competition among living things and in their adjustment to their environment. Not alone does the fitness of the organism to its environment determine its survival, but the fitness of the environment to the organism and the ability of the latter to find its proper place in nature. Many a square peg has gone down in the battle of life because it failed to find a square hole, among lower organisms as well as among men.

The problem of geographical distribution then is that of finding the place of origin of any given type of life, the reasons for, and the routes and methods of its spread from its center of origin, as well as the manner of its adaptation to the surroundings, both biological and physical, in which it lives today.

As the explorer setting forth upon an unknown journey concerns himself first of all with his equipment and means of travel, so must the student of bio-geography consider primarily the factors which determine the dispersal of plants and animals throughout the world. Animals of strong flight, like most birds and bats, are relatively unhindered in their movements and consequently these groups are of world-wide distribution. The greatest traveler in the world is the arctic tern which spends its summers amid the arctic snows, where its newly hatched young have been found surrounded by a wall of freshly fallen snow scraped out of the nest by the parent bird, and journeys south 11,000 miles to spend its winter on the shores of the antarctic continent. Many



THE ARCTIC TERN

The greatest traveller in the world. From Cooke, "Bird Migration," in Bulletin Bureau of Biological Survey.

other birds make semi-annual journeys of close to 10,000 miles and the great majority of them travel long distances on their migrations. Bats also migrate long distances, this fact offering a possible explanation of their presence on some oceanic islands, otherwise destitute of native mammals.

Marine animals, especially fishes, are often widespread in their distribution because of their powers of migration and the relative absence of barriers within the sea, but fresh water fishes are generally limited more or less closely to the area in which they occur. No general rule however can be laid down.

Among terrestrial animals the greatest travellers are the mammals and these often perform long journeys, a habit characteristic of the bison "that ever-journeying animal, which moves in countless droves from point to point of the

vast wilderness; traversing plains, pouring through the intricate defiles of mountains, swimming rivers, ever on the move. . . . These great migratory herds of buffalo have their hereditary paths and highways, worn deep through the country, and making for the surest passes of the mountains, and the most practicable fords of the rivers. When once a great column is in full career, it goes straight forward, regardless of all obstacles; those in front being impelled by the moving mass behind. At such times they will break through a camp, trampling down everything in their course.

"It was the lot of the voyagers, one night, to encamp at one of these buffalo landing places, and exactly on the trail. They had not been long asleep when they were awakened by a great bellowing, and tramping, and the rush, and splash, and snorting of animals in the river. They had just time to ascertain that a buffalo army was entering the river on the opposite side and making toward the landing place. With all haste they moved their boat and shifted their camp, by which time the head of the column had reached the shore, and came pressing up the bank.

"It was a singular spectacle, by the uncertain moonlight, to behold this countless throng making their way across the river, blowing and bellowing, and splashing. Sometimes they pass in such dense and continuous column as to form a temporary dam across the river, the waters of which rise and rush over their backs, or between their squadrons. The roaring and rushing sound of one of these vast herds crossing a river, may sometimes in a still night be heard for miles."¹

The common houseratt is sometimes a wide traveler. "Migrations of rats have often been recorded. Pallas narrates that in the autumn of 1727 the brown rat arrived at Astrakhan in southern Russia from the east in such numbers and in so short a time that nothing could be done to oppose them. They crossed the Volga in large troops. The cause of the migration was attributed to an earthquake; but since similar movements of this species often occur unattended by earth disturbance, it is probable that only the food problem was involved in the migration which first brought the brown rat to Europe.

"In nearly all countries a seasonal movement of rats from houses and barns to the open fields occurs in spring, and the return movement takes place as cold weather approaches. The movement is noticeable even in large cities.

"But more general movements of rats often occur. In 1903 a multitude of migrating rats spread over several coun-

¹Irving, "The Adventures of Captain Bonneville," U. S. A., p. 354. By permission of G. P. Putnam's Sons.

ties of western Illinois. They were noticed especially in Mercer and Rock Island counties. For several years prior to this invasion no abnormal numbers were seen, and their coming was remarkably sudden. An eyewitness to the phenomenon informed the writer that as he was returning to his home by moonlight he heard a general rustling in the field near by, and soon a vast army of rats crossed the road in front of him, all going in one direction. The mass stretched away as far as could be seen in the dim light. These animals remained on the farms and in the villages of the surrounding country, and during the winter and summer of 1904 were a veritable plague."²

Even the humble field mouse may perform long pilgrimages. "The lemmings, also, a small kind of rat, are described as natives of the mountains of Kolen, in Lapland; and once or twice in a quarter of a century they appear in vast numbers, advancing along the ground and 'devouring every green thing.' Innumerable bands march from the Kolen, through Northland and Finmark, to the Western Ocean, which they immediately enter; and after swimming about for some time, perish. Other bands take their route through Swedish Lapland to the Bothnian Gulf, where they are drowned in the same manner. They are followed in their journeys by bears, wolves, and foxes, which prey upon them incessantly. They generally move in lines, which are about three feet from each other, and exactly parallel, going directly forward through rivers and lakes; and when they meet with stacks of hay or corn, gnawing their way through them instead of passing round. These excursions usually precede a rigorous winter, of which the lemmings seem in some way forewarned."³

Reptiles and Amphibia, because of their inadequate means of locomotion and their sluggish habits, are poor travellers and their dispersal must be due in the main to natural increase or to purely passive causes such as transfer of eggs by currents of water or to the agency of man.

Apart from the insects the invertebrates are for the most part inactive migrants, and here too dispersal is mainly passive, though some animals, such as the squid or octopus, are active swimmers, and probably travel considerable distances "under their own steam," so to speak.

The means of passive dispersal of animals are numerous and varied. In the transport of marine animals currents play the greatest part. In this way animals are carried great distances at sea, distances which are limited only by the animal's power of survival and by the extent of the cur-

² Lantz, "The Brown Rat in the United States," pp. 16-17.

³ Lyell, "Principles of Geology," 11th ed., Vol. II, p. 361.

rent itself. Even land animals may be carried over wide stretches of water by winds and currents. The late Alfred Russell Wallace records the transport of a boa constrictor from Africa to St. Vincent, two hundred miles away, on a floating cedar tree. Polar bears have occasionally been stranded upon the shores of Iceland by icebergs. Lyell quotes an early observer to the effect that "wolves, in the arctic regions, often venture upon the ice near the shore, for the purpose of preying upon young seals, which they surprise when asleep. When these ice-floes get detached, the wolves are often carried out to sea; and though some may be drifted to islands or continents, the greater part of them perish, and have been heard in this situation howling dreadfully, as they die by famine. According to the same authority travellers in the Amazon country have on several occasions observed monkeys, squirrels, crocodiles and other animals journeying down that river on rafts of floating trees and tangled vegetation. Four pumas from such rafts are reported to have visited Montevideo in one night."⁴

Fresh water invertebrates may be carried by currents of water or attached to the feet of birds, or by the wind in the case of the eggs or cysts from the bottom of dry pools.

Man's rôle in the spread of the animal inhabitants of the earth is a very important one. The early Spanish explorers brought horses to South America in 1537, "and the colony being then for a time deserted, the horse ran wild; in 1580, only forty-three years afterwards, we hear of them at the Strait of Magellan!"⁵ The spread of the English sparrow and the brown rat, both introduced species from Europe, is too well known to need repetition here, while the devastation wrought among the trees of New England by the brown-tail and the gypsy moths, is a warning example of the danger of disturbing the scales which Nature ordinarily holds so nicely balanced.

The spread of animals and their occupation of the earth resolves itself into a great obstacle race, and "the race is not always to the swift." The barriers to the spread of animals are manifold—temperature, moisture, sunlight, chemical character of water, mountains, rivers, lakes or seas, deserts, forests and treeless plains are all barriers to various kinds of animals. Temperature is probably the greatest obstacle to the dispersal of marine animals. Were it not for the tropics intervening between the temperate and colder seas of north and south their distribution would probably be world

⁴ Lyell, *locus citatus*, p. 366.

⁵ Darwin, "Voyage of a Naturalist," p. 233. D. Appleton and Company.

wide, but temperature is usually, though not always, a very effective barrier to their spread. This was strikingly illustrated by the disappearance of the tilefish off the Atlantic coast some years ago, which has been described in a previous chapter. Currents may serve not alone as a means of transport for inactive forms, but through temperature differences as a barrier to their spread, as well. Northern animals drifting southward in the Atlantic under the influence of the Labrador current, sweeping past the shores of Labrador and Newfoundland, may be caught by the Gulf Stream moving toward the northwestern coasts of Europe, and their southern journey terminated.

During the cruise of the U. S. Bureau of Fisheries steamer in 1884, Captain Tanner reports that on July 20, when off the mouth of Chesapeake Bay "we passed numerous dead octopods floating on the surface. This unusual sight attracted immediate notice and no little surprise among those who knew their habits, as it was not suspected at first that they were dead. . . . These dead cephalopods were seen frequently on the 100-fathom line and outside of it, from the position given above to the meridian of Montauk Point, a distance of 180 miles. They were less numerous however as we went to the northward and eastward. Several dead squid were seen also, and two specimens were picked up with a scoop-net."⁶

"From the Barents Sea we know many instances of a similar destruction of animals on a large scale. The case of the boreo-arctic fish, the capelan . . . is specially striking, millions of this fish having occasionally been found drifting dead at the surface. In the Barents Sea very sudden changes of temperature occur, and it is natural to conclude that the death of the fish is caused thereby. The greatest destruction of this kind probably occurs among the young stages, eggs and larvæ of fishes. As we shall see later, these young stages may be removed by currents very far from the places where they are capable of developing, and in all probability they are liable to encounter catastrophes which sweep them off in enormous numbers."⁷

So too the chemical environment prevents the invasion of inland waters by marine forms and *vice versa*, although this is not true of those fish like the shad and salmon, which ascend the rivers at spawning time. In such cases however the age and sexual maturity of the fish determine their movements, so that at most times of the year with these fish as well

⁶ Tanner, "Report of U. S. Fish Commissioner for 1884," p. 32.

⁷ Murray, "The Depths of the Ocean," pp. 707-8. By permission of the Macmillan Company.

as others the salt content of the water does limit their distribution. The extent to which fresh water fish can withstand salt water and *vice versa* is still a moot question, but the salt content certainly does play a determining rôle in the distribution of all fish.

The inhabitants of inland waters also find the chemical environment one of the determining factors in their distribution. Here one may find all degrees of salinity from fresh or slightly saline waters, to those such as the Dead Sea in Palestine or the Great Salt Lake of Utah, containing much greater amounts of salt than does the ocean. Corresponding to the differences in the saltiness of these inland waters there are marked differences in the kinds of life inhabiting them.

The barriers to the spread of land animals are more numerous than are those which affect aquatic forms. As with the latter so too with these does temperature play an important part. Every one is familiar with the great differences between the animal life of the tropics and the poles, and equally marked are those which strike the observer as he ascends some lofty mountain, and the more so the farther south the mountain lies. Mountain ranges have a notable influence in separating one fauna from another. The animal life of the Great Plains of the east is distinctly different from that of the Great Basin to the west of the Rocky Mountains. Wide stretches of desert present an impassable obstacle to most forms of life, while bodies of water may with equal emphasis say to the animal wanderer "Thus far shalt thou go, and no farther."

Plant journeys are wholly passive ones, and affected mainly by the carriage of fruit or seed by wind, water and animals. The tumble-weed driven across the prairie by the wind and heaping itself up in great piles along the fences, the down of the dandelion as it floats idly through the air on a summer afternoon to settle softly in some protected corner of your front lawn, and the long-awned heads of the fox-tail grass tumbling merrily over field and roadside all bear emphatic testimony to the part played by wind in the spread of plants, especially those which are an unmitigated nuisance; while any one who has watched a dog disentangling himself from a coat full of burs will realize the important rôle played by animals in plant distribution. One of the most important factors in plant distribution is man himself. To prove this one need only follow a railway track or a highway and note the never-ending succession of weeds, which are distributed thereon. Many of the most common and pestiferous members of plant as well as of animal and human society are im-

migrants from Europe—witness the Russian sow thistles, the wild radish and the barnyard grass.

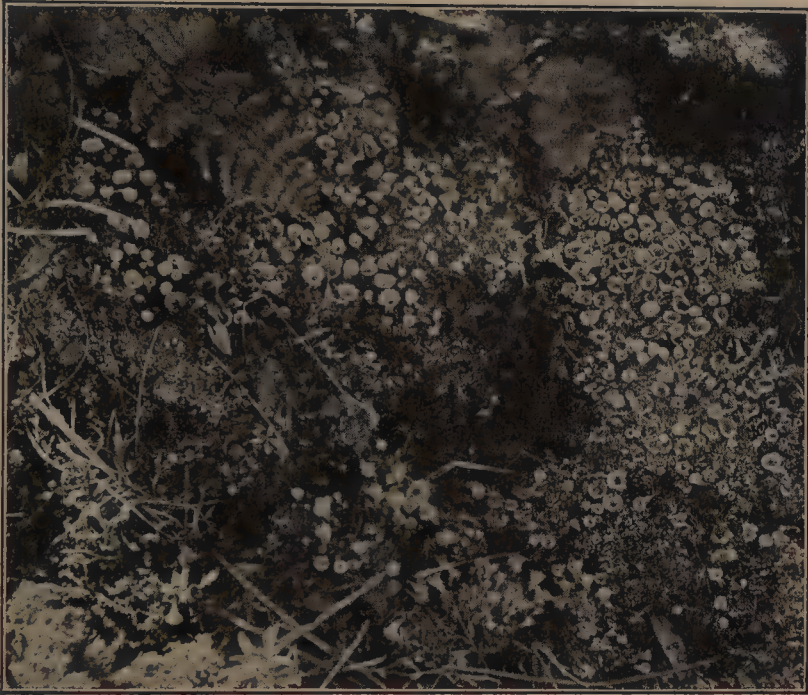
To discuss in any detail the past movements and distribution of plants and animals in North America would in itself fill a more than ample volume. In the preceding chapter some of the great movements of animal life in North America have been briefly mentioned, and under the present heading it must suffice to consider briefly some of the facts and problems of present day distribution and of the relations of plant and animal societies to one another and to their surroundings.

The study of plant ecology, that is, the study of the plant at home, as an individual and as a member of society, owes its inception in America to the work of Pound and Clements, who in their "Phytogeography of Nebraska" in 1897 described the plant societies of that state and developed new and more accurate methods for their study. This was followed in 1905 by Clements' "Research Methods in Ecology," in which the whole field of plant ecology and the methods for its investigation were presented. Following the appearance of these works came a host of papers dealing with various phases of plant ecology, the most comprehensive of which is that of Clements on "Plant Succession."

When an area of land is denuded of its plant covering, as happens far too often in our fire-swept forests, or as a result of floods or landslides; or when a new area appears as in the case of the drying up of a lake or the shifting of a river, there is an inrush of plant settlers to occupy the virgin soil. The character of the new settlers depends upon many factors—the character of the new soil, the relative proximity of adjacent species of plants, the ease with which the seeds or runners of these plants can reach the new territory and their readiness to establish themselves there after their arrival. The arrival of the new settlers will depend upon all the many factors which determine plant dispersal—strength and direction of wind currents, presence of streams and rainfall, drainage which may carry seeds on to the new area, and the abundance and movements of seed-bearing animals.

In the broken chasms of mountain fastnesses, where the shattered peaks that were, now lie in a mass of tumbled ruin, or upon the sheer slopes of granite cleft by some contortion of the earth, the humble lichen finds its home. In some small chink or crevice of the rock where a few drops of water linger from the winter's snow, its filaments take hold, and when the breath of summer dries its niche it lies dormant waiting for the rain or melting snow. Through the acids secreted by these lichens, and by the hardy, drouth-resistant mosses

which soon join them, and by the more powerful action of the frost, and the ever-wearing action of the dust blast driven by the wind, the rock is gradually crumbled into dust, which together with the decay of moss and lichen forms a little soil, in which other mosses may take root; and by and by the seeds of a few hardy grasses find a place, and by their roots the wind and rain-borne dust is caught and soon a little turf



A LICHEN SOCIETY

Lichens are among the earliest invaders of a rocky surface, preparing the way for higher plants to follow.

Courtesy of the Conrad Lantern Slide Company, Chicago.

is formed. Now some hardy perennials wander in, and their stouter roots serve as wedges to pry apart the smaller chips of rock and aid in making new soil. And in course of time a heather society is formed, made up of grasses and the low-growing matted bodies of perennial herbs, mingled with a few annuals, which live but a single year. And now some hardy shrub, perchance a mountain willow, or it may be a seedling pine comes in, and ever and anon new trees take root and grow, decay of root and leaf and fallen stem adds to the humus soil, and in the shadow of the growing trees sun-loving plants die out and shade-lovers take their place; and now a forest stands where once was barren rock.

So too the deathbed of a lake is the birthplace of a new community of plants. In the shallow margins of the lake rises a miniature forest of cat-tail, rush and sedge. With the gradual shrinkage of the lake through evaporation or drainage, and the slow accumulation of wind-borne dust and débris on its bottom, runners of rush and sedge press further from the shore. Their decaying stems and leaves, together with wind-borne sediments form ever-increasing mud in the shallow water, which with the recession of the lake forms a fertile field for the advancing grasses along its shores. And thus a meadow is formed into which soon come the moisture-



A GLACIAL POND IN THE ROCKY MOUNTAINS
Showing the encroaching forest. Original.

loving herbs, and then from near or far wind-driven catkins come and willows grow from these, the vanguard of the forest; which soon are joined by other trees, of various sorts, dependent on proximity and ease of carriage of their seeds; and thus a young forest takes its stand upon the old lake bottom and meadow herb and grass give place to trees and plants which love the dark—the victors in the “struggle for existence.” Where however forests are far away or soil and climate are not adapted to growth of trees, the grasses persist and a meadow marks the graveyard of the lake.

The inter-relationships of the various members of plant communities, both to one another and to their environment,

are well nigh as varied as are those of human society. Temperature, moisture, wind and light are the four principal parts of the plant's environment, but these in turn are dependent on other factors, such as altitude, topography and soil. The structure of the plant itself determines its response to these factors and its survival or extinction, while the relation of plant to plant in determining such factors as light, food supply, growing space, etc., and the inter-relationship between plants and animals, affecting transport of seeds, and forage for herbivorous animals, all have a life and death meaning in the existence of the plant.

Not only is the distribution of plants determined in large measure by that of animals, but even more is the occurrence of the latter dependent upon that of the former. Especially

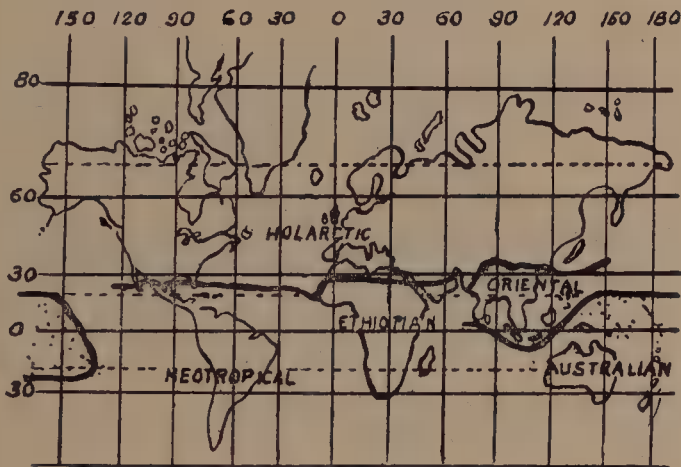


DIAGRAM OF THE SIX GREAT ZOÖGEOGRAPHICAL REALMS OF THE EARTH
After Sclater and Wallace.

is this true of herbivorous types, which necessarily are dependent upon the presence of their forage plants. The movements of grazing animals, such as horses and cattle, are in particular dependent upon the abundance of grasses, and in the early days of the West, Indians and white men alike guided their movements in the search for buffalo largely by the condition of the prairies over which the bison roamed. Not only are the herbivorous types dependent on the vegetation in their movements, but also the carnivorous animals which prey upon the former. In the northern forests the movements of the deer in winter largely determine those of their enemy, the wolf. During the mouse plague in the Humboldt Valley in Nevada in 1907-8 the abundance of the mice attracted thither large numbers of hawks to feed upon them.

Based on the distribution of their animal inhabitants the

zoögeographer divides the earth into five great realms, which are more or less overlapping but which show in a broad way the arrangement of animal life upon our globe. These realms are the Holoarctic, including North America to Mexico, Europe, northern Africa, and most of Asia; the Neotropical, comprising South and Central America and Mexico; the



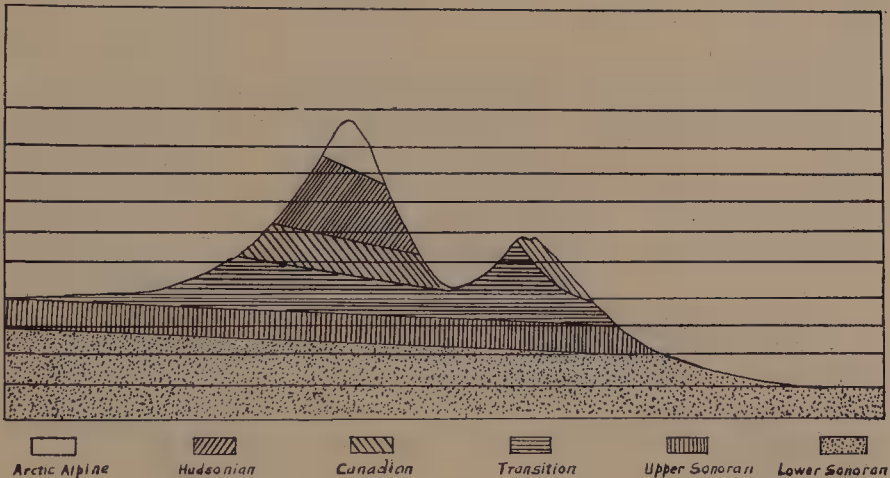
AFTER U. S. BIOLOGICAL SURVEY

Ethiopian, Africa, south of the Sahara; the Oriental, India and most of the Malay Archipelago; and the Australian, Australia, New Zealand, the southeastern portion of the Malay Archipelago and the South Sea Islands.

In the study of the geographical distribution of animals (especially birds and mammals) in the United States and in the correlation of their distribution with that of plants, the principal agency has been the United States Biological

Survey, although the studies of other workers, especially those of Allen on mammals and Jordan on fish, have contributed largely to our knowledge of this subject.

The Biological Survey divides North America into zones of plant and animal life based primarily on temperature, which zones may be subdivided to a large extent on the basis of moisture. These zones follow in a very broad way the parallels of latitude in the lower country and the levels of altitude in the mountains. Let us take for an example San Francisco Mountain in northern Arizona, whose life zones have been studied by Doctor Merriam, the former chief of the Survey. The zonal distribution of life shows somewhat more



PROFILE OF SAN FRANCISCO AND O'LEARY PEAKS IN ARIZONA

To illustrate their life zones. The left side of the diagram is S. W., the right is N. E. The horizontal lines indicate contour intervals of 1,000 feet. Modified after Merriam's "Biological Survey of the San Francisco Mountain Region . . . Arizona," *North American Fauna*, No. 3.

clearly in the case of an isolated group of mountains such as those of which San Francisco Mountain forms the principal peak, than it does in an extended range such as the Rockies or the Sierra Nevada, where the zones are more or less broken up by the irregular contour of the mountains, with their jumbled masses of peaks and valleys. These mountains further include more zones from base to summit than do those of like altitude further north, where the temperature range from base to summit is less.

San Francisco Mountain is located in north central Arizona on the elevated plateau through which the Colorado River has cut its titanic chasm. The town of Flagstaff, site of the Lowell Observatory, from which the late Professor Lowell

brought us so many wonderful messages from Mars, is located near its southern base. The mountain, 12,794 feet in height, marks the grave of an extinct volcano, and several lesser volcanic peaks rise from the plateau near the main peak.

If we reverse the usual order of things and fancy ourselves deposited by aeroplane on the summit of the peak we shall find ourselves in a treeless, wind swept area of "bare vol-



AN ALPINE DWARF

At 13,000 feet on Pike's Peak, Colorado. From "Plant Indicators."

Courtesy of Doctor F. E. Clements and the Carnegie Institution.

canic rock," which even in this southern latitude (35°N.) is snow-clad for three-fourths of the year. Here many of the herbs tend to form spreading rosettes, their leaves keeping close to the earth, and sending up a short flower stalk from the center. In the intense sunlight of the clear mountain air, growth is rapid and flowers and fruits mature early. To paraphrase an old saw the plants make fruit while the sun shines. Most of them are species occurring on high moun-

tain summits and arctic lands in North America, while some extend around the world. On the mountain summits they form isolated groups, cut off from their congeners of the north by the wide intervening plains and valleys. How have they come there? In glacial days, when the ice sea swept southward to New Jersey, Illinois and Nebraska, and glaciers covered the higher slopes of our western mountains, plants and animals were forced to move before it; for the Ice King is an inexorable landlord, and when he undertook to dispossess the tenants of the lands there was no gainsay-



PIKA, OR ROCKY MOUNTAIN HARE

An inhabitant of rock slides both above and below timber line. Photo by E. R. Warren. From Metcalf, "Organic Evolution,"

By permission of the Macmillan Company.

ing his wishes in the matter. But with the retreat of the ice the former tenants returned to their old abodes. Some of them however instead of moving north once more after the retreating ice, found a more convenient path up the mountain sides and thus came to settle in a new home, on the bleak mountain tops where they found the climate to their liking.

So too the animal life of alpine summits contains many species, common alike to mountain top and barren ground of the far North, though the number reported for the San Francisco Mountain is too few to allow any generalizations con-



PTARMIGAN IN SUMMER PLUMAGE
Photo by E. R. Warren.



PTARMIGAN IN AUTUMN PLUMAGE
Photo by E. R. Warren.



PTARMIGAN IN WINTER PLUMAGE
Photo by E. R. Warren.



CLARKE'S CROW
A characteristic bird of the high mountains.
Photo by E. R. Warren.

cerning them. On alpine summits of the Rocky Mountains and Sierra Nevada however one meets with several more or less characteristic species. Here the marmot's whistle and the sharp call of the pika or mountain hare, mingled with the harsh note of the leucosticte, and the pipit's plaintive call are carried across the barren slopes by the rush of the wind. Here too is the home of the ptarmigan, whose changing fashion with the changing season—white in winter, mottled black,



TIMBER LINE IN THE ROCKY MOUNTAINS

Alpine firs at 11,000 feet altitude on Long's Peak, Colorado. From "Plant Indicators."

Courtesy of Doctor F. E. Clements and the Carnegie Institution.

buff or white in summer—matches them so closely with their background, that one stumbles upon them before he is aware of it. The birds seem to realize their protection, for they are very tame and may sometimes be killed with a stick or stone. This tameness is however more likely due to infrequent molestation. The ptarmigan is also a characteristic member of the arctic community nesting on the tundras of the far north, together with the little lapland longspur and the snow bunting, whose change of coat in spring and autumn resembles that of the ptarmigan. Even the gauzy-



POLAR BEARS

Courtesy of the National Zoölogical Park.



THE CARIBOO

Photo by Elwin R. Sanborn.

Courtesy of the New York Zoölogical Society.



MUSK OXEN

Inhabitants of the barren lands. Photo by Elwin R. Sanborn.
Courtesy of the New York Zoölogical Society.



THE WOLVERINE

A prowling marauder of the north woods.
Courtesy of the New York Zoölogical Society.



CANADIAN ZONE FOREST IN COLORADO

The spruce tree in the middle foreground is a striking example of symmetry. Original.

winged butterfly may be found flitting over the barren lands of the Arctic and the highest mountain peaks. Many other types of insects may also be found here.

Over the ice and snow fields of the Arctic the polar bear holds sway, the mortal enemy of the seal, while the arctic fox plays the part of a hanger-on at court, feasting upon the remains of seal which drop from the royal table. Over the tundras of the barren lands, covered with an abundant vegetation in the brief summer, roam the musk ox and the barren ground caribou, while the arctic hare, the marmot and the lemming or northern mouse, find a table plentifully spread with roots and grasses.



THE WOODCHUCK

Photo by Elwin R. Sanborn.

Courtesy of the New York Zoological Society.

Descending from the barren summit of the mountain to timber line one encounters the outposts of the forest at an altitude of 11,500 feet in the form of stunted spruce and pine, "whose gnarled and weather-beaten forms bear testimony to the severity of their struggle with the elements."

Below timber line one comes to a rather indefinite zone characterized by spruces and fox-tail pines. Many of the plants characteristic of this zone on San Francisco Mountain are represented by the same or closely related species in the "upper spruce belt of the higher Alleghenies, the Rocky Mountains, the Cascades, and the Sierra Nevada, and . . . the great northern spruce forest of Canada." Here live several



THE WEASEL IN ITS WINTER DRESS
Photo by Elwin R. Sanborn.
Courtesy of the New York Zoölogical Society.



THE SNOWSHOE RABBIT
So named from its large feet.
Photo by Elwin R. Sanborn.
Courtesy of the New York Zoölogical Society.

animals which extend further down into the following zone, the Hudsonian possessing so little that is characteristic that it may perhaps best be included in the following or Canadian, and the two grouped together as the Boreal zone. The Canadian zone, which on San Francisco Mountain lies between 9,500 and 8,200 feet, is characterized by the Douglas spruce, the limber pine, balsam fir and aspens. In the Boreal zone on San Francisco Mountain occur a number of animals characteristic of this zone in Canada and the mountains in the



CANADIAN AND TRANSITION ZONE LANDSCAPE

Fir forest of Canadian zone at left, open pine timber of transition zone at right, showing effect of slope exposure.

Courtesy of the U. S. Bureau of Biological Survey.

United States. Some of the better known which inhabit it throughout the United States and Canada are the elk, moose and woodland caribou; the weasel, fisher, martin, mink, red fox, wolverine, gray wolf; the marmot or woodchuck, porcupine, pika and snowshoe rabbit; most of the mountain sheep and the Rocky Mountain goat, which is not a goat at all, but a relative of the European chamois or antelope. "The mammals of this sub-region (boreal) are largely of old world origin, many of them coming in with the great immigrations of the Pliocene and Pleistocene epochs, but there are also native American elements and even one genus of South

American origin, the short-tailed or Canada porcupine."⁸ Of birds there are a large number of characteristic species, a mere enumeration of which would hardly carry conviction to the general reader.

Leaving behind us the forests of Douglas spruce and balsam fir, we enter an open "forest of stately pines . . . which average at least . . . 100 feet in height. There is no undergrowth to obstruct the view, and after the rainy season the grass is knee-deep in places. . . ." This forest covers the mountain side between 7,000 and 8,200 feet, some of its trees extending even to 8,800 feet among the spruce and fir. It



THE BEAVER

From a group in the American Museum of Natural History.

Courtesy of the Museum.

marks a debatable area, where boreal forms come down comingling with southern types, and hence has been aptly termed the transition zone. It has but few distinctive species either on San Francisco Mountain or elsewhere, being characterized rather by a mixture of types. In general it occupies the northern half of the United States, bending far southward along the mountain ranges, and running north along the river valleys, which serve as paths of northern invasion for southern forms. Southern animals which cross

⁸ Scott, "History of Land Mammals of the Western Hemisphere," p. 151. By permission of the Macmillan Company.

the transition zone include the mountain "lion" or puma, which extends his prowling path from Patagonia to Canada, the Canada lynx, a skunk, the raccoon, badger and one of the deer. *Vice versa* Canadian mammals extending across the transition zone southward into the Sonoran include the chipmunks, beaver, meadow mouse (*Microtus*) and the muskrat.



GROVE OF ASPENS OVERFLOWED BY A BEAVER POND
With the dam and stumps cut by beaver in the foreground. Original.

Below the yellow pine forest on San Francisco Mountain we reach the region of piñon pines and red cedars which extends between 6,000 and 7,000 feet, while below this we leave the mountain and enter the desert. Both of these latter areas belong to the southern or Sonoran life area in North America, so named from the province of Sonora in Mexico, which is at or near the center from which its characteristic

species have migrated into the United States. There are several birds (jays and titmice) which are characteristic of the piñon belt on San Francisco Mountain and a few mammals (mice and ground squirrels), while several lizards come in from the "Painted Desert" to the east. Two species of lizards however appear to be characteristic of this zone, and one (a horned toad) wanders up into the transition zone above.



CYPRESS SWAMP, ARKANSAS

Courtesy of the U. S. Bureau of Biological Survey.

But temperature is not the sole factor regulating the distribution of animals and plants. Moisture, light, the character of the soil and the surface of the country—these and other factors, all work together and influence one another to determine this distribution. Perhaps the most important of these is moisture. The traveller passing across the United States from east to west, finds himself at the outset of his journey on the moist plain of the Atlantic Coast, a region which has but recently (in geologic time) been raised above the level of the sea. Along the New England Coast, the cold Labrador current in its southward sweep, produces the fogs which so often shroud these shores, while the Florida peninsula receives the moisture laden winds from both the Atlantic

Ocean and the Gulf of Mexico, and is drenched with the abundant rainfall of the tropics. Characteristic of the coastal plain and the eastern slope of the Appalachian Range to the west are several species of pines, the low sandy areas of the plain being largely characterized by these trees, which have given their name to the New Jersey "Pine Barrens."

Upon the slopes of the mountains and in the valleys of their intersecting rivers, are the remains of some splendid hardwood forests of maple, oak, elm, linden, hickory, beech

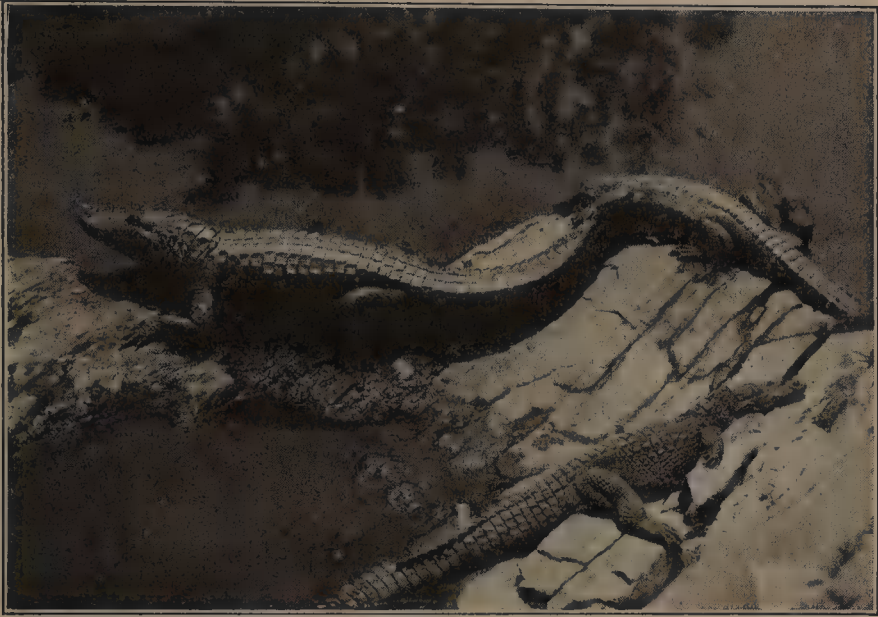


COTTON RAT AND NEST

Courtesy of the U. S. Bureau of Biological Survey.

and chestnut, while in the swamps of the South are the cypress, magnolia and palmetto.

In its large features the animal life of this region does not differ from that of the Canadian, transition and upper Sonoran zones of a western mountain, which has already been described; although differing therefrom in many minor details. But along the southeastern coast occur a few species which distinguish this region from other parts of the country. In the rice fields of the South occurs the rice rat, while the cotton rat is another animal characteristic of the South Atlantic and Gulf States. The Florida Everglades are



ALLIGATORS ENJOYING A QUIET SIESTA
Photo by Elwin R. Sandorn.
Courtesy of the New York Zoölogical Society.



THE WATER MOCCASIN
An inhabitant of the lowlands of the South Atlantic and Gulf States.
Courtesy of the New York Zoölogical Society.

included in the tropical zone, which except here and at the mouth of the Rio Grande does not enter the United States. In the streams of southern Florida lives the alligator, while the dark forests are the home of the parrakeet, an intruder from the numerous family of parrots in South and Central America. A hundred years ago this bird ranged as far north as the Great Lakes, but it is at present restricted to a few areas in our Southern States, if indeed it is not wholly extinct at present.

Crossing the Appalachians our traveler descends into the



THE BURROWING OWL

Photo by Elwin R. Sanborn.

Courtesy of the New York Zoölogical Society.

great valley of the Mississippi River, with its branches stretching far to east and west and draining nearly half the total area of the United States. Here he at first encounters a climate not greatly different from that of the eastern seaboard, although subject to somewhat greater extremes of temperature. The fauna and the flora too are similar to those of the Atlantic Coast. As he passes westward however out of the basin of the Mississippi, rising over the slope of the Great Plains to the foothills of the Rockies, the climate changes, the rainfall materially decreasing and the temperature extremes increasing.

Accompanying these changes of climate occur marked changes in the life of the land. The eastern forests disap-



PRAIRIE DOG



PRAIRIE DOG AT BURROW

The "dog towns" of the West are familiar objects.
Courtesy of the U. S. Bureau of Biological Survey.

pear save for a fringe of timber along the stream bottoms, giving place to the vast prairies of the west. New types of animals also appear upon the scene. Squatting on his haunches outside the entrance to his subterranean home the prairie dog squeaks defiance at the passing traveler, and the burrowing owl utters its shrill cry in protest at the presence of the intruder. Several species of ground squirrels or gophers are characteristic members of the animal community, some of which extend eastward across the Mississippi. The black and white of the lark bunting is a conspicuous feature of the landscape, while the magpie in his coat of green and white lends color as well as noise to the cottonwood groves along the rivers. The Great Plains form an interesting "tension line," as the biologist calls it, "where east is west and west is east and ever the twain shall meet."⁹ The eastern and western movement of the western and eastern flora and fauna respectively is one of the most interesting features of this area. The dickcissel, one of the sparrow family, a characteristic bird of the Mississippi Valley, has only in recent years ventured from his ancestral home across the vast prairies to the west. Conversely the magpie appears to be moving slowly eastward. The red-eyed vireo, whose home is in the eastern United States, appears within recent years to have followed the Missouri Valley westward, crossed the Rocky Mountains and established itself in the northwestern United States and British Columbia.

An interesting suggestion as to how the migration routes of various birds may have become established, many of which are very devious and hard to explain, is to be found in the route of this bird. Wintering in South America, it moves northward in spring following the course of the Mississippi River to near its headwaters, whence it turns northwestward across mountains to its breeding grounds in the North. A much shorter route lies west of the Rockies; but inherited instinct (or is it parental example?) carries the bird in the path of its forefathers far from the course which is most easy and direct.

Another interesting case of recent extension of a bird's breeding range is furnished by the bobolink, which is an inhabitant of marsh and meadow land. With the settling of the arid territory of the West, accompanied by its irrigation, the bobolink is accompanying the western march of empire, and settling itself in Nevada, Oregon and other western states.

Between the Rockies and the Sierras lies the Great Basin, scorched with the torrid heat of summer and frozen with the icy blasts of winter, a land parched with endless drouth.

⁹With apologies to Mr. Kipling.



THE HORNED TOAD

Which is not a "toad" at all, but a lizard, resembling in its scaly attire a miniature monster of the past.

Photo by Elwin R. Sanborn.

Courtesy of the New York Zoölogical Society.



THE KANGAROO RAT

Characteristic of the arid Southwest.

Courtesy of the U. S. Bureau of Biological Survey.

The life of this region is widely different from that of the East, but the mere enumeration of the names of its inhabitants would be of little interest. Many of its species are inhabitants of the ground and bushes and are more or less bleached in color corresponding to the background upon which they live. How this adaptation has been effected no one can surely say. But more of this in a later chapter. One of the most characteristic of its inhabitants is the "horned toad," which is not a toad at all, but a lizard. This little creature with its horned head is a miniature Triceratops, the giant dinosaur which once shambled across our plains.

The towering Sierras rising like a mighty wall shut off the Great Basin from the interior valleys of California, and these in turn are separated from the Pacific Coast by the Coast Range of mountains, which while pygmies compared



THE GILA MONSTER

Characteristic of the arid Southwest. From Ditmars, "Reptiles of All Lands," in "National Geographic Magazine," Vol. 22.

with their mighty neighbors to the east, nevertheless form a very efficient climatic barrier to the moisture laden winds sweeping landward from the sea. The climatic differences thus caused are reflected in the life of the interior valleys and the coastal slope. In no similar area in North America are there such great extremes of climate or more marked differences in the corresponding life. Especially is this true of Death Valley in the interior of southern California, whose lowest point is 276 feet below the surface of the sea. Here the temperature in summer frequently reaches 125°F. in the shade, and the relentless sun scarce ever hides its shameless face behind a cloud. Here lives a little community of desert dwellers, for the most part characteristic of their arid home.

The fauna and flora of California are peculiar to themselves, following however the general principles of distribution of life elsewhere. Here occur the Goliaths among plants—the California big trees. At one time in the past

these trees were widely distributed over North America, but today they are restricted to our western coast,¹⁰ and it may be are doomed to extinction.

Among the most characteristic, and withal attractive members of California society are the humming birds, a group occurring only in America. The several species found along



A CALIFORNIA BIG TREE GROVE

Courtesy of the U. S. Bureau of Biological Survey.

the Pacific Coast and the few occurring elsewhere are invaders from the tropics where most of the more than four hundred species find a home. Another interesting inhabitant of southern California and Arizona is the great condor, which spreads its wings from eight and a half to eleven feet.

Dwelling in the damp forests of Oregon and California

■ *Sequoia gigantea* is limited to a few small areas in California, while *S. sempervirens* or the "redwood" extends north along the coast into Oregon.

is the last representative of a once thriving family, which at one time had a much wider distribution than at present. The sewellel is an animal somewhat resembling a large rat, which digs his home among the roots of the forest trees and stores therein the harvest which he gathers from its herbs.

Several million years ago, more or less, there lived in North America a numerous race of animals related to the opossum and kangaroo, the marsupials, to which reference has been made in the preceding chapter. Then they disappeared from what is now the United States, for what reason we do not



MOUNTAIN BEAVER, OR SEWELLEL

Courtesy of the U. S. Bureau of Biological Survey.

know—a mysterious disappearance of the past, which the palæontological sleuth may never solve. The most likely explanation is that they were driven south by the wolves and tigers and others of their ilk, the robber barons of the animal world. More recently one of their number, the opossum, has once more ventured northward as far as the northern United States (Michigan and New York).

Have all these facts laboriously gathered by many men in many years any practical value? Even had they none they would still be well worth while because of the light which they, in conjunction with the “hard facts” of palæontology,

throw upon the great questions of evolution, adaptation and the vicissitudes and changes of plants and animals in the past. But apart from this purely "theoretical" interest they have an important bearing upon human life today, for they give us a clue to the suitability of any region for crops of a given type. Thus if a settler in a given region wishes to know what kind of crops will grow best in his region, it is essential for him to know, not only the character of the soil in his area and the amount of rainfall, temperature range, etc., but the type of plants which will grow well in that particular climate, or in other words the life zone in which his area lies. To make this information available to our farmers the Biological Survey has prepared a life zone map of the United States and Canada, together with a list of the various cereals, fruits and vegetables best adapted to each zone.

Thus does the biologist seek to make his knowledge "practical" in the rendering of service to the world.

CHAPTER VI

Experimental biology. Preformation in a new dress, organization of the egg, regeneration and grafting, plastic surgery, tissue culture, the problem of death, and immortality of the cell.

The last thirty years have seen remarkable developments in the field of experimental biology. True it is that the method of experiment was a very early one, especially among human and plant physiologists. Nevertheless experimental biology has lagged behind experimental physics and chemistry and has but recently found its proper place among the other branches of biological science. In the development of this field Germany and America have played the leading part, while with the recent upheaval in Europe, and consequent check to scientific progress there, the coming era of reconstruction finds this country better fitted than any other to lead in the development of the new science.

While the earlier biologists were in the main satisfied with the observation of phenomena, and speculation as to their causes, the experimental biologist demands that these phenomena shall be analyzed under certain imposed conditions, in order that their causes may be scientifically ascertained. Thus the method of transmission of yellow fever could only be conjectured until the Yellow Fever Commission in 1900, by exposing subjects to all possible conditions of infection, proved that the bite of the mosquito (*Stegomyia*) was the only natural means of transfer.

Experimental biology has followed a few main lines of thought, with many side lines which are branched and interwoven with one another in an intricate maze. A general review may best be given by tracing the main lines, the branches being followed only so far as they are essential to an understanding of the former. The principal questions then with which we shall deal are the following:

Are the factors which determine the development of an organism internal or external? Why does an organism grow old and die? What are the factors of organic evolution? Is the organism a machine, governed by the laws of physics and chemistry, or is there a "vital principle," an "entelechy" or a "soul," transcending in its activity the bounds of the purely material universe?

A century and a half ago Caspar Friedrich Wolff overthrew

the generally accepted doctrine of preformation, according to which the adult animal was present in miniature within the egg or the sperm cell, both of which had their advocates, so that embryologists were divided into the rival schools of "ovists" and "spermatists." One enthusiastic and imaginative observer even pictured a miniature human body within the spermatozoön.



BEROË

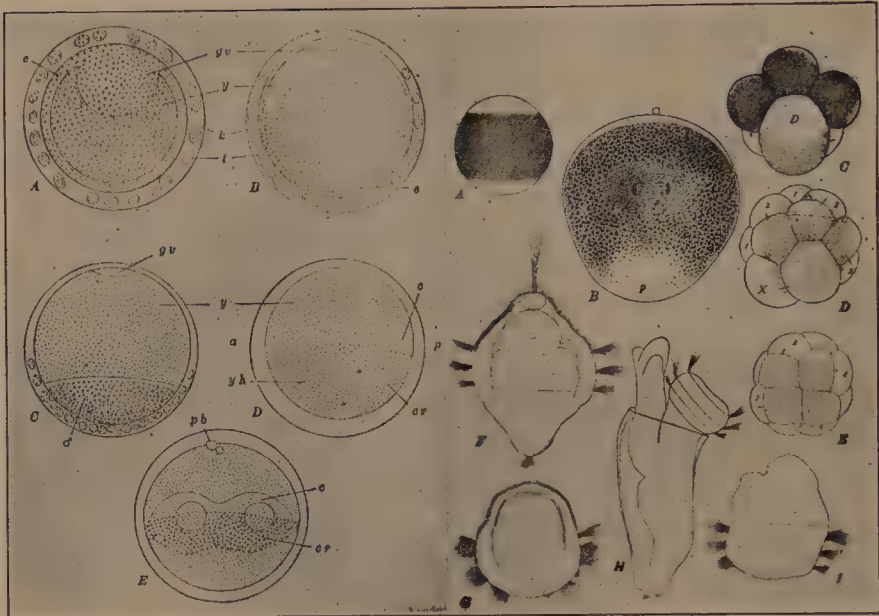
Showing the four rows of swimming plates, sp. From Lankester, after Chun.

While such fancies have long since been laid to rest, preformation, in a new dress, is playing a very important rôle on the biological stage today. The importance of this theory is due largely to the work of two American biologists—Morgan at Columbia and Conklin at Princeton.

In modern form preformation assumes the presence in the sex cells of certain formative stuffs or entities (more exact terminology is impossible in the present state of our knowledge) which determine the development of parts or features of the adult organism. These things, whatever they are, may reside either in the nucleus or the cytoplasm. In the former

case they are present in both sperm and egg cell; in the latter case only in the egg, the amount of cytoplasm in the typical sperm being too small to contain the "organ-forming substances."

If such formative stuffs are unequally distributed to different daughter cells in the division of the egg, then we should expect each of these cells to give rise to a definite part of the embryo and to that part only. If, on the other hand, these



(Left) THE EGG OF THE TUNICATE CYNTHIA

Showing the "organ forming substances" and their distribution in different stages. a, anterior; p, posterior pole of egg; c, clear protoplasm; cr, yellow crescent; e, cortex containing yellow pigment; g.v., germinal vesicle; k, chorion; p. b., polar bodies; t, test cells; y, yolk; y. h., yellow hemisphere; o, sperm nucleus. From Kellicott, after Wilson.

(Right) DEVELOPMENT OF THE MOLLUSC DENTALIUM

A, distribution of materials in undivided egg; B, commencement of division showing the "polar lobe" p, which in C and D (division stages) is found at D and X respectively. In E the cell X is absent, the polar lobe having been removed at an earlier stage. F and H, normal larvæ of twenty-four and seventy-two hours, respectively, G and I, larvæ of the same ages lacking the "polar lobe" material. From Kellicott after Wilson.

stuffs are equally distributed to the daughter cells, then these cells should be mutually interchangeable, and any one of them, if isolated from its fellows, should give rise to complete, though dwarfed embryos. Is the egg a mosaic, or is it uniform in its structure?

The ctenophore *Beroë* has normally eight rows of ciliary bands. After one division of the egg, if the two resulting

cells are separated, each one will develop into a half larva, with only four rows of bands. Similarly each cell of the four and even the eight cell stage may be made to develop into a partial larva with two or even only one row of bands. And further if a part be removed from the egg before division, a defective larva is the result.

The egg of the ascidian *Cynthia* has been shown by Conklin to contain at least five different "organ-forming substances," distinguishable by color and texture, which are symmetrically placed with reference to the median plane of the embryo, but differentially located antero-posteriorly. If one of the first two cleavage cells (for example the right) is killed, the other develops into the opposite (left) half of the body, which contains all the normal parts, but of one-half the normal size. But if in the four cell stage, when the second cleavage has differentiated the anterior from the posterior ends of the body, one or both of the anterior or posterior cells is killed, the resulting larva lacks those parts which are present only in the cells which have been destroyed.

A similar result has been obtained by Wilson in the egg of the mollusc *Dentalium*, in which three different substances can be identified. Thus the yolk is here at first located at one pole of the egg, and later in a single one of the cleavage cells. If this "yolk lobe" be removed from the egg, when it starts to divide, the resulting larva lacks certain parts (foot, mantle, shell, etc.) normally formed from the yolk cell.

Centrifuging the egg of *Cynthia* with consequent disarrangement of the organ-forming substances may so disturb the development that the resulting larva may be turned inside out, with entoderm on the outside and ectoderm within.

At the posterior end of one of the chrysomelid beetles (*Calligrapha*) occurs a disk of granules, which seemingly function as germ cell determinants, for if the end of the egg containing this disk be pricked, and its component granules allowed to escape, or if the disk be destroyed with a hot needle, and the egg is then allowed to develop, the resulting embryo lacks germ cells.

There are many experiments however which point to different conclusions. Thus in eggs of fresh water snails and certain annelids, substances of different color and specific gravity occur, but these may be displaced from their normal positions by centrifuging, without in any way affecting the development. This has led Lillie and others to the conclusion that the so-called organ-forming substances are not in reality such, but merely an accompaniment of a more profound organization resident in the protoplasmic framework

of the egg, which cannot be mechanically rearranged by centrifuging or otherwise.

The foregoing experiments seem to show conclusively that the developing animal is in some sense at least preformed in the egg. No less conclusive however is the evidence of a directly opposite character. In *Amphioxus* and many *Hydromedusæ* isolated cleavage cells give rise to complete though dwarf larvæ, while on the contrary it has been possible in some cases (*Ascaris*, *Sphærechinus*) to produce normal, though giant larvæ, by the fusion of two eggs or embryos. Many intermediate forms exist between those eggs in which one of the cleavage cells produces a partial, and those in which it forms an entire larva. In some cases, as for instance in certain echinoderms, an isolated cleavage cell may undergo at first a partial development, but later a process of regulation may ensue, resulting in the formation of a complete larva. Different results may be obtained in the same animal, depending on the method of experimentation. Thus if one of the first two cleavage cells of a frog's egg be destroyed with a hot needle and the egg left in its normal position a half embryo results, but if the position be inverted a whole embryo develops in the majority of cases.

In this maze of conflicting evidence a final word can scarcely be spoken. Undoubtedly different eggs differ in the extent of their organization. If a part of the egg of the nemertine *Cerebratulus* be removed prior to fertilization, no disturbance of development ensues. If the two cells of the first cleavage are separated, they undergo for a time a partial cleavage, but very soon the normal development is resumed. But if one of the four cells, resulting from the second cleavage, be isolated, partial development proceeds for a longer time than in the preceding case, the normal process not being resumed until much later. We find here a possible explanation of the divergent behavior of different eggs. In some the embryo may be preformed in the egg, in others only in later stages of cleavage.

The phenomena of regeneration speak strongly for the uniformity of both egg and adult. If the parts of the organism are predetermined in the former, then when one of these parts is lost its replacement should be impossible; but if the egg be isotropic (one part the same as another), and if this uniformity persist in the adult, then a lost part should be replaceable.

The ability of regeneration in many animals has long been known, being mentioned by Aristotle and Pliny. In the middle of the eighteenth century, the famous work of Trembley on *Hydra* attracted widespread attention and several workers entered this field.

Regeneration occurs to a greater or less extent in all the great groups of animals and plants. If Hydra be cut into several pieces each will develop into a new animal. Earthworms and flatworms can regenerate either head or tail if these be removed. The starfish can have a new arm made to order; the lobster a claw; the snail may acquire a new head, and the sea cucumber a new stomach. In higher plants a piece of leaf or root may give rise to an entire new plant.

Among animals the regenerative power decreases with increasing specialization. The relative size of a piece of Hydra necessary to produce a new animal is much less than that of a crab or a frog. In vertebrates the amphibians have been most used for regeneration experiments. There are many salamanders which can regenerate legs or tail, but there appear to be differences in the regenerative ability of different forms. Age has an influence, as well as degrees of specialization, for while the tadpole will readily regenerate a lost limb the frog is unable to do so.

In man the power of regeneration is relatively slight, although skin, muscles, bone and other tissues show this power to some extent in the healing of wounds, while the lens of the eye may occasionally regenerate. There are some remarkable cases on record of regeneration of internal organs in mammals, although these are sometimes merely cases of hypertrophy of part of an organ, in compensation for the loss of another part of that same organ, rather than instances of true regeneration. Thus the removal of one-half or even three-fourths of the liver of a dog or rabbit may result in the enlargement of the remainder, without any replacement of the lost part. It is well known that in man injury to a lung or kidney may be compensated by increased growth and activity of its opposite. There are recorded instances however of true regeneration of internal organs in mammals. In the rabbit removal of as much as five-sixths of a salivary gland may be followed by complete regeneration, and the kidney of a rat or a rabbit may develop new tissue to a certain extent, after part has been removed.

The regeneration of the lens in vertebrates has been a bone of contention among zoölogists for many years. In the development of the normal eye there first arises an evagination of the primary forebrain forming a primary optic cup or vesicle, which is shortly followed by an invagination of the adjacent ectoderm to form a secondary cup or vesicle, from which is formed the lens. The question at issue is: Is the lens dependent upon the presence of the primary vesicle for its development, or may it arise independently of the latter? Many ingenious experiments have been performed, principally on amphibian larvæ, in the attempt to solve this

problem, with unfortunately widely divergent results. The ectoderm has been cut around the developing primary vesicle, and the flap folded back so as to expose the latter; which has then been excised, the flap replaced and the wound allowed to heal. In other experiments the primary vesicle has been supposedly destroyed by pricking it with a hot needle; and in still others the vesicle has been transplanted to a strange area of the same, or a different species, such as the abdominal wall. In the latter experiments lenses have been formed from parts of the ectoderm which never give rise to them in nature, and similar results have been obtained by destroying a lens already formed, thereby causing its regeneration from the iris.

In the former experiments the results have been inconsistent, a lens sometimes regenerating and sometimes failing to do so, after the removal of the primary vesicle. Werber has suggested that this apparent inconsistency is due to the incomplete destruction of the vesicle in some cases in which it had supposedly been entirely removed, and the consequent formation of a "lens stimulus" by small pieces of the vesicle which remained. Of interest in this connection are the experiments of Stockard, Werber and others in the production of Cyclopean and other monsters, which will be considered later. In some of these experiments a single median eye has been produced in place of two lateral ones, with the resultant formation of a single lens associated with the single eye, and the absence of any lateral lenses. In other cases lenses have developed at almost any place on the monster, apparently unassociated with any optic material. Werber has suggested however that these so-called "independent lenses" owe their origin to the stimulus of microscopic bits of optic vesicles scattered over the body of the monster, through a process of blastolysis or tissue destruction induced by chemical or osmotic action, and in some cases he is able to demonstrate what he considers bits of such material in close proximity to these lenses.

Whatever the truth of the matter may be, the evidence is I think conclusive that lenses, and presumably other organs also, are not in any sense preformed, but result from the interaction between the parts of the organism itself and their environment.

Nearly related to experiments on regeneration are those on grafting. The custom of grafting in plants has been practised by horticulturists for a long time. Trembley with his celebrated work on *Hydra* was a pioneer in this field among animals. More recently this work has been continued by King, Rand, Peebles and others in this country. The anterior end of one *Hydra* may be grafted onto the posterior

end of another; two Hydraz may be united by either anterior or posterior ends, or one Hydra may be grafted onto the side of another. The results differ depending upon the conditions of the experiment, and the species of Hydra employed; but the general result is that a process of regulation ensues whereby a new animal is formed, similar in size and proportion to the normal individual. One of the most interesting results bearing on the question of predetermination of parts is that obtained by grafting two Hydraz by their anterior ends and then cutting off the posterior end of one near the graft line. In this case a new head forms on the



FOUR-LEGGED TADPOLES

Produced by transplanting the limbs from one tadpole to another. After Harrison, "Journal of Experimental Zoölogy," Vol. 4.

(originally) posterior end of the graft, where a head, in the ordinary course of events would never develop.

Some of the most interesting grafting work of recent years has been done by Harrison, in connection with studies on the developing nerve fiber. Two positions have been held on this question—one, that the axone of the nerve cell, the conducting part of the nerve fiber, arose *in situ* from surrounding cells; the other, that the axone was an outgrowth from the nerve cell itself. The latter view appears to have been definitely established by Harrison. Our interest here however centers primarily upon certain secondary results of Harrison's work rather than upon the question of nerve fiber development. In these experiments Harrison has shown that limb buds can be transplanted from one tadpole to another, the tail of one

species of tadpole can be grafted on that of another species, two entire animals may be united, and even the head of one species (*Rana virescens*) can be united to the body of another (*R. palustris*), and a young frog reared from the combination. Similar results have been obtained by Crampton in the union of the pupæ of moths, combinations of cecropia moths with promethea and polyphemus moths having been successfully made.

Most remarkable of grafting results with higher animals



A COMBINATION FROG

With the head of one species grafted onto the body of another. The tadpole to the left, the adult to the right. From Harrison, in the "Anatomical Record," Vol. 2.

have been those of Carrel on mammals. He has removed sections of arteries of one animal and replaced them with pieces of vessels taken from another. He has even made this graft successfully with vessels which had been kept in an ice chest for several weeks after death. Thus a piece of a human artery taken from an amputated leg and preserved for twenty-five days in cold storage was used to replace a piece of the aorta of a small dog. The graft took and the dog recovered and lived for over four years, during which time she bore several litters of puppies, finally dying during

labor. A post-mortem examination showed the grafted vessel to be slightly dilated and lacking muscular tissue, but otherwise normal. Carrel's success in grafting vessels enabled him to transplant entire organs. He performed this operation on cats' kidneys, with a certain amount of temporary success, the transplanted organ functioning for a number of weeks. Ultimately however the animals died. But even the temporary success of so daring an operation gives ground for hope that complete success may ultimately be possible.

Grafting on the human body or plastic surgery is supposed to have been practised by the Egyptians as early as 1,500 B. C. In recent years great advances have been made in this branch of surgery, and not only have skin, bones, muscles, fascia and tendons been transplanted, but parts of internal organs have been used to repair defects in other parts. Thus the urethra has been replaced by the appendix and a vagina has been made from a piece of intestine. A piece of cornea from a human eye kept in cold storage for eight days has been successfully used to partially restore the sight of a man blinded by alkali.

The story of the recent achievements of surgery in repairing the features of soldiers, who had been so badly wounded as to be merely caricatures of their former selves, reads almost like a tale from the "Arabian Nights." Jaws, noses, ears, cheeks, almost entire faces have been remade, so that the victims have in the end presented a fairly good facsimile of their former selves. While details cannot be given here, a brief outline of the method may be of interest. A former picture of the patient if available is taken as the model of what the surgeon aims to make. Then a piece of bone of the proper size and shape to refit the lost part (a jaw or nose) will be cut out of a rib or shin bone and inserted beneath the skin of an adjoining part (the neck or forehead). After the skin has attached itself to the inserted bone, the latter is cut out on three sides, leaving a stalk on one side to maintain the circulation, the skin is now cut open around the scar and the new member inserted in the open cavity. The adjoining skin is attached to the insert, and after the graft has "taken," its stalk is cut away, and when finally healed the skin is massaged, and the scar removed in this way as far as possible. Thus a fairly natural part may be made to replace a jawless mouth or a repulsive hole where a nose once grew.

Carrel and others have shown that not only blood vessels and cornea, but also skin, fascia, tendon, bone and cartilage may be preserved in a condition of latent life for weeks or months in cold storage, and still be used successfully for transplantation. Thus pieces of skin taken from the body

of an infant, which died during labor, and preserved in vaseline at a temperature of $+3^{\circ}\text{C}$. were successfully used for grafts after forty-two days; and pieces of fat, bone and cartilage taken from amputations have been similarly preserved in cold storage for varying lengths of time, and later used in grafting operations. Seemingly the day is not far distant when cold storage will supply us with our tissues as well as our foods.

The liberties which may be taken with living tissues and their ability to grow in strange surroundings is I believe strong evidence for the plasticity of the cell, showing as they do the profound influence of environment on its development. Such a view of course must not be pushed too far. It would



THREE STAGES IN THE RECONSTRUCTION OF A WOUNDED SOLDIER'S FACE

From Esser in "Annals of Surgery," Vol. 65.

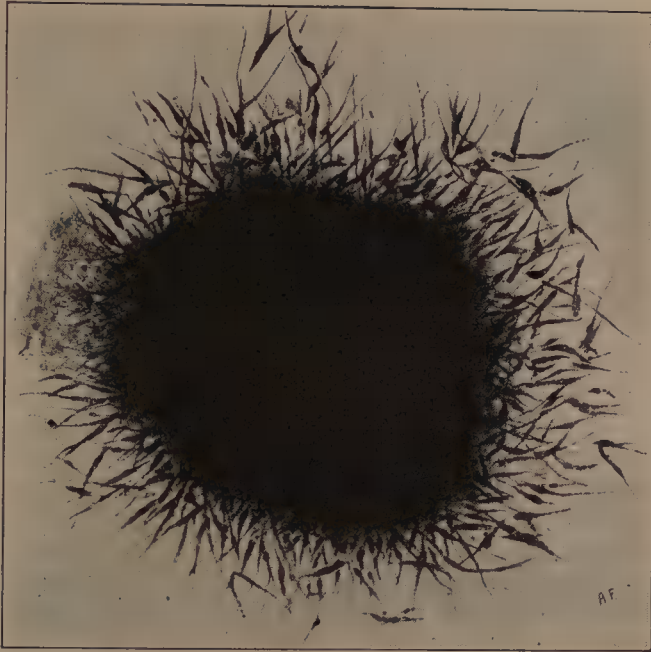
By permission of J. B. Lippincott Company.

be absurd to expect that every cell could be modified by its surroundings so as to form every other kind. With high specialization the cell loses *pari passu* its adaptability. But in the lower organisms there is abundant evidence of the ability of cells to be molded into new structures, even after they have reached the usual limits of their development.

Further evidence in favor of this view is afforded by the apparently unlimited power of reproduction possessed by certain cells. If the development of the organism were pre-determined in the egg, then the growth of its parts should be limited, and there should come a time in its development, as ordinarily there does come in the life of the individual, when growth should cease and the power of repair should not exceed the need created by waste. But in some cases, notably

in cancer, certain cells possess the power of seemingly unlimited growth, increasing at the expense of other tissues, running wild within the body, and finally destroying it as a result of their riotous living. This power of seemingly unlimited growth of the cell may in many cases be initiated artificially.

Unquestionably the most important of Harrison's results



A PIECE OF GROWING TISSUE

The dark center is the original tissue, the branching bodies radiating out from it are the growing cells. It has been possible to cultivate in glass cells many different kinds of tissue, including those from man himself. This method has been used for studying the growth and reaction of cancer cells, and may throw light on the cause of this dread malady. After Lambert and Hanes, "Journal of Experimental Medicine," Vol. 13.

on nerve growth was his development of the method of growing tissues outside of the animal body. He transplanted bits of the central nervous system of the tadpole to drops of coagulable lymph from the frog, and by placing these in a glass cell under the microscope, he was able to follow the growth of the nerve fibers. More recently a large number of workers, mostly Americans, have developed Harrison's method and applied it to both embryonic and adult tissues of birds and mammals. The method has been applied to the

study of the growth not only of normal but of pathological tissues, such as tumors and cancers.

When a bit of tissue is removed from a living, or recently killed animal, and placed in a suitable medium (blood plasma is the one mostly employed) at a proper temperature, it sooner or later, depending on the age of the animal from which it is taken, begins to grow, sending out sheets of cells in all directions into the surrounding medium. After a time however growth ceases, but may recommence if the tissue be removed, washed and transferred to a fresh medium. In this way tissues have been kept alive for more than nine years and carried through nearly two thousand transfers. Carrel has grown chick tissues in this way, which had been kept in cold storage for six days, and even human tissues taken from a cadaver several hours after death may grow.

But what is death if our tissues, as well as our actions, will live after we are gone? Does the grim specter lie in wait for us in the coils of our intestines, as Metschnikoff would have us believe? Or is it the hardening of our arteries which ushers us into the great unknown? Is death inherent in life, or were the first living things immortal, and death an adaptation secondarily acquired for the benefit of the race, although working to the detriment of the individual, as Weismann has suggested?

For an answer to these questions let us turn to the unicellular organisms and see what they have to teach us. If a single *Paramœcium* be put in a fresh infusion of hay in water it soon divides to form two daughter cells, which divide again in their turn, and so on; until the infusion is teeming with millions, all offspring of one cell, which is still living in its descendants. For this reason Weismann maintained that the Protozoa were immortal. But after a time reproduction ceases and the *Paramœcia* begin to die off. The culture has passed its climax and begun to retrograde. Finally the *Paramœcia* disappear entirely, unless fresh material be meantime added to the culture. But if this be done the cells acquire a new lease of life and commence to multiply again as merrily as ever.

By using a varied culture of hay, leaves, moss, etc. in rotation and transferring his animals daily to fresh culture, Woodruff has carried a race of *Paramœcia* through some seven thousand generations extending over a period of twelve years, without any evidence of degeneration. While an exact analysis of the different stimuli controlling the *Paramœcia* in a hay infusion has not been made, it has been shown pretty conclusively that waste products materially check their growth, while purity of the culture in this respect stimulates

growth and keeps the animals healthy. The food supply must also exercise a controlling influence, the growth of bacteria, which serve as food, being also checked by waste products (toxins) in the culture. It can be shown however that even in the presence of abundant food supply, stale culture will inhibit the growth of *Paramœcia*.

We can compare the metazoan with a culture of *Paramœcia*, all descendants of one cell. The former, as well as the latter, starts as a single cell (the fertilized egg). After a period of active division or growth the climax is reached, when the processes of repair can only keep pace with those of waste, and from then on the organism passes through the decline of old age followed by death. But if a few cells be removed from the parent body and transferred to a fresh medium (blood plasma) they forthwith start to grow abundantly, and this growth can apparently be maintained indefinitely, if the transfers be repeated from time to time.

The influence of the age of the animal from which the plasma is taken is very marked. In that from young animals growth is much more active than in that taken from adults, but if an extract of the tissues of a young animal be added to the latter the growth is materially increased.

May not then old age and death be caused by waste products excreted by the cells of the metazoan body? May it not be a process of auto-intoxication, not localized as Metschnikoff suggests, in the intestines, but generalized throughout the entire body? Whatever answer to this question the future may make, the faculty of unlimited growth possessed by most, if not all the tissues of higher animals, suggests not only the indeterminate nature of development, but also the inherent immortality of the cell.

CHAPTER VII

Experimental biology continued. The rôle of the chromosomes in inheritance. Inheritance of sex and sex-linked characters.

In the preceding chapter we have considered the question of the influence of the cytoplasm upon development, particularly in respect to the "organ-forming substances" which it contains; and the ability of one part of an organism to regenerate, not only itself, but some other part normally foreign to it. We shall now consider the rôle of the nucleus in development, especially that of the chromosomes.

Whether or not development be locally predetermined in the egg, there is of course no question that the latter is predetermined in its general development. Men do not gather "grapes of thorns or figs of thistles," nor can the specific, e. g., characteristic of the species, development be altered by any change in the environment. What is it then which determines the specific characters of the organism?

While the theory of cellular units responsible for the hereditary transmission of specific and individual characters, originated with Darwin as the well known "pangenesis" theory, in an attempt to explain the origin of new characters by environmental influence, and was amplified and more definitely formulated by Weismann, it has never received stronger support than through the epoch-making work of Morgan and his students at Columbia University within the last decade.¹

In order to appreciate the significance of this work, it is necessary to turn back the pages of time for a half century and pause a moment to look into the garden of the monastery at Brünn in the Tyrol, where the monk Gregor Mendel was busy with his peas.

Mendel was monk and later abbot at Brünn, and for a time

¹I do not wish in this statement to accuse modern biologists of accepting Darwin's theory of "pangenesis" in its entirety. Darwinian and modern viewpoints have in common however the assumption of some sort of cell units, be they physical or be they chemical, which are responsible for reappearance in the offspring of characters present in the parent.

taught the physical and natural sciences in the monastery school. While monk and teacher he was essentially a great investigator, and in spite of his other duties, he found time to perform a large number of breeding experiments with sweet peas, the results of which he published in 1865 in the "Proceedings of the Natural History Society of Brünn." This paper, which he sent to his friend Nägeli the botanist, made no impression on the latter and attracted no attention, until thirty-five years later, when Mendel's principle was independently discovered by three botanists—DeVries, Correns and Tschermak. Since then, Mendel's discovery has been recognized as one of the greatest in biology, and his paper has become a great scientific classic.

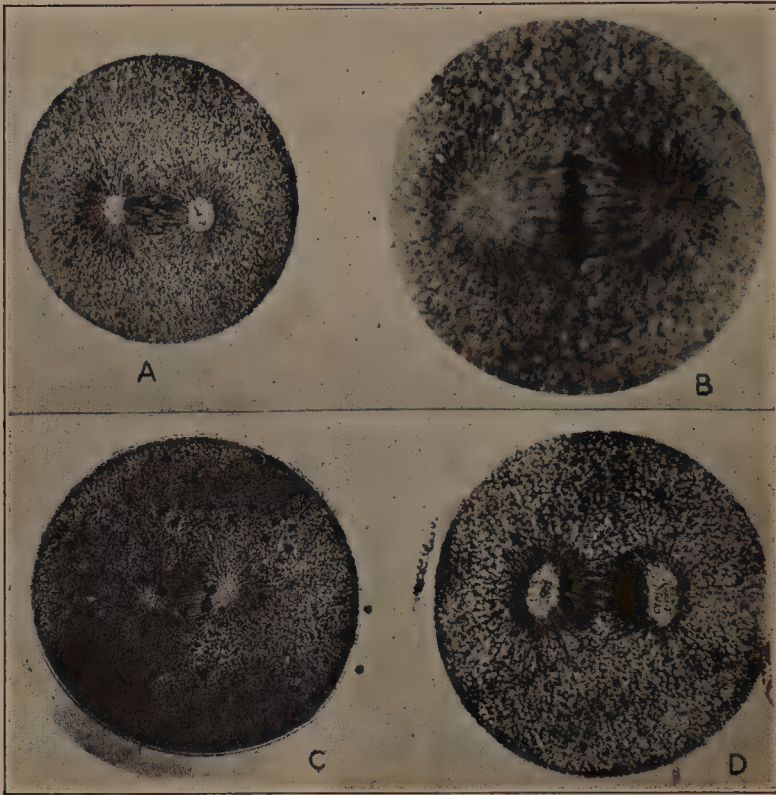
The results of his work have been so extensively quoted, and are known so widely and so well that their rehearsal is needless here. There are certain features of his results however which, while well known to biologists, are perhaps not fully appreciated by the general reader, and which it may therefore be worth while to emphasize. Thus it is commonly known, for example, that a cross between a tall pea and a dwarf produces only tall offspring, which, when bred together, produce, on the average, three tall and one dwarf descendants. But the meaning of this well-known Mendelian ratio is possibly not widely understood. A ready explanation is found however in the behavior of the chromosomes of the germ cells, prior to, and during fertilization.

The nucleus of an undividing or resting cell contains a substance known as chromatin, which, when the cell is sectioned and stained for microscopic study, appears as a mass of deeply stained blotches and specks scattered indiscriminately over a very delicate network of threads or "linin" fibrils. When the cell becomes active and starts to divide this chromatin material is gathered together into an irregular twisted thread known as the "skein" or "spireme," which is at first long and thin, but soon shortens and thickens and then breaks up into a number of segments in the form of rods, loops or balls, the number of which is characteristic for any given species of plant or animal, but which varies in different species from two to upwards of two hundred. In division these chromosomes are equally divided so that each new cell receives the same number as the parent cell contains.

But when the animal or plant is ready to reproduce there is a striking difference in the behavior of the chromosomes—a difference to which is probably related all the varied and wonderful phenomena displayed by Mendelian inheritance.

Nearly forty years ago Van Beneden ascertained that the germ cells of *Ascaris*, an intestinal parasite of the horse, each contained, at the time of fertilization, one-half the number

of chromosomes characteristic of the species; which number was therefore restored at the time of fertilization by the union of the egg and sperm nuclei. Now, if this reduction in number can be shown to involve the separation of definite



PHOTOGRAPHS OF CHROMOSOMES

Showing various stages in the division of a sea urchin's egg. The minute dark masses at the center of the egg are the chromosomes. The light areas, surrounded by dark radiations to either side of the chromosomes are the "asters," so-called from their star-like appearance. Biologists are still in the dark as to the cause of this wonderful process of cell division. In certain respects it closely resembles an electromagnetic phenomenon, the poles of the magnet being located at the centers of the asters. These chromosomes are more delicate than the finest filament of a spider's web. Fig. B is magnified 3,000 times, the others 1,500. After Wilson, "Atlas of Fertilization and Karyokinesis of the Ovum."

By permission of the Macmillan Company.

chromosomes from one another so that different sex cells receive different chromosome combinations, then an ideal arrangement exists in the cell, for realization of the Mendelian results. Referring to the case of the tall and dwarf peas, let us suppose that both partners in the cross are "pure,"

e. g., that all the germ cells of the tall pea carry the determiner for tallness (T) and all those of the dwarf pea the determiner for dwarfness (t). If now we cross the tall (T) with the dwarf (t) we shall have in the cells of the hybrid both T and t, and the result will be a tall pea (since tallness dominates dwarfness) carrying latent the determiner for dwarfness.

Before the germ cells of the hybrid are ready for fertilization they must undergo a process of ripening or maturation in the course of which the chromosomes of each are reduced to one-half the number in the body cells of the species. This reduction is effected by the union of the chromosomes in pairs and their subsequent division as apparently single, though in reality double elements. One of these divisions, known as the "reducing division" is *assumed* to separate the paired elements from each other. If now we assume that the determiner for tallness be carried by one chromosome and that for dwarfness by another, and that these two chromosomes pair with one another in the maturation of the germ cells of the hybrid, separating from each other in the reducing division, then the germ cells of the latter will be of two kinds, e. g., those containing the T chromosome and those containing t. Now when the hybrids are crossed with one another there will be three possible combinations resulting from the union of their germ cells, in the following ratio (1TT, 2Tt, 1tt), which results from the chance combination of T and T with t and t. These chance results may be demonstrated by a simple experiment. If four billiard balls, two black and two white, be shaken together in a box and drawn out in pairs, one-fourth of the drawings will be two blacks, one-fourth two whites and one-half a black and a white. If then the behavior of the chromosomes at the time of maturation and fertilization is as assumed, and if secondly the chromosomes carry "determiners" (whatever they may be) for the characters of the organism; then the Mendelian results must follow as a mathematical necessity of the chance separation and recombination of the chromosomes in the maturation and fertilization of the germ cells.

	T	t
T	TT	Tt
t	Tt	tt

Diagram to illustrate inheritance of size in the sweet pea. A cross of a tall with a dwarf pea produces 3 tall and 1 dwarf pea in the second generation.

We have used a number of "ifs" in the above discussion. Are our conclusions based purely on assumptions? Let us see. In the case cited we have assumed in the first place

that chromosomes carrying the alternative determiners for tallness and dwarfness pair with each other and later separate in the maturation divisions, going into different germ cells. Now it is manifestly impossible to locate directly the determiners for any character in any particular chromosome, or in the chromosomes at all, for that matter. The direct analysis of the chromosome is as yet impossible. Nor can we prove directly that the paired chromosomes separate from each other in the maturation divisions, instead of retaining their paired character and dividing equally.

We have however certain indirect evidence which strongly supports our assumptions. In many species of animals and plants, notably among insects, the chromosomes differ mark-

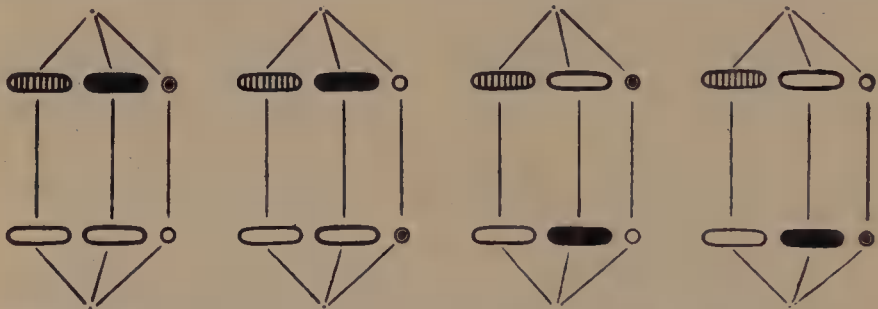


DIAGRAM SHOWING EIGHT POSSIBLE DISTRIBUTIONS OF THREE PAIRS OF CHROMOSOMES IN THE MATURATION OF THE GERM CELLS

After Morgan, Sturtevant, Muller and Bridges, "The Mechanism of Mendelian Heredity."

By permission of Henry Holt and Company.

edly in size or shape. In the equatorial plates of most mitoses these chromosomes are very definitely arranged in pairs with similar members. But after the reduction division, when the chromosome number is reduced by half, the resulting cells each receive similar groups of chromosomes, so that each chromosome of one cell, has its exact counterpart in its sister cell, with certain exceptions in the case of the sex chromosomes to be noted later.

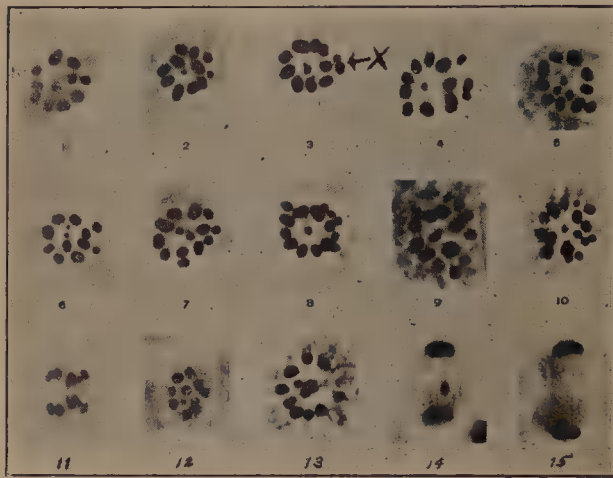
Seemingly then we are warranted in our conclusion that in the reduction division the members of each pair are separated from one another and distributed to sister cells. And further, since the male and female sex cells each contain similar groups of chromosomes, it is reasonable to assume that similar or "homologous" chromosomes from male and female pair with each other in fertilization, remaining paired until the next generation of germ cells matures, when they separate to be recombined once more in the succeeding fertilization.

[illegible]

It is by no means certain however that the determiner is a fixed and unchangeable unit. In fact, the very reverse is undoubtedly the case. Chemical analysis of the exceedingly complex components of the cell is very difficult, and the results vary widely. All observers are agreed however as to the great complexity of protoplasm. According to Miescher, nuclein, which forms the major part at least of the chromosome, has the formula $C_{29}H_{49}N_9P_3O_2$. Now there are certain substances, especially among the compounds of carbon, that wonderfully kaleidoscopic element, which analysis shows to have the same structure, but which nevertheless exhibit different properties. These differences are explained on the assumption that while the molecules of these substances con-

² Computed by Professor E. F. Chandler, of the University of North Dakota. Even should the above figure be greatly reduced by linkage it would still be so large as to be absolutely incomprehensible.

tain the same number and kinds of atoms, the latter are differently arranged in the molecules. Such molecules differing in the arrangement of their component atoms, are known by the somewhat formidable term of stereoisomers. Miescher has shown that serum albumen for example has a possibility of 1,000,000,000 stereoisomers. Now if nuclein has one-tenth as many and if each determiner in the human chromosome consists of but a single molecule of nuclein, the number of possible arrangements within the nucleus of the fertilized egg becomes so great as to be wholly beyond the range of human ken.



PHOTOGRAPHS OF CHROMOSOMES

From an insect magnified 1,500 times. The pair of sex chromosomes is shown at x in Fig. 3. In Figs. 14 and 15, which show the chromosomes divided into two groups, each of which passes into a new cell, the larger one of the pair, which "determines" the female sex, is seen passing to the lower group. After Wilson, "Journal of Experimental Zoölogy," Vol. 6.

Still stronger evidence of the behavior of the chromosomes as outlined above is afforded by that of the sex chromosomes, which have been found in a large and ever increasing number of animals. Like the devils in the herd of swine on the shores of Galilee, the number of hypotheses regarding the cause of sex, which have in times past infested the human mind, is legion. As early as the eighteenth century Drelin-court enumerated 262 untenable theories of sex determination, and as Blumenbach aptly said, "Drelincourt's theory formed the 263rd." Since then, possibly as many more sex theories have blossomed and withered without bearing fruit. Recent investigation indicates that sex determination is in Nature's

hands, and that the most which man can experimentally accomplish is to influence the survival ratio between males and females.

In many animals, including insects, myriapods, arachnids, nematodes, echinoderms, fowls, amphibians, rats, guinea pigs and man, differences occur in the number or size of the chromosomes of the male and the female. In some cases one sex, usually the female, has from one to several more chromosomes than the male; in others there is a size difference between two chromosomes of a corresponding pair, which consists in the female of two large chromosomes, in the male, on the



GYNANDROMORPH FRUIT FLIES

Courtesy of Professor T. H. Morgan.

contrary, of a large and a small element. The “accessory” or sex chromosome may occur either free or attached to another chromosome, while the relative differences in size between the unequal members of a pair of sex chromosomes varies all the way from equality in the two members to absence of the smaller one.

The process of sex determination in these forms is briefly as follows: In the reduction division in the maturation of the sex cells in the male, the members of the unequal pair of sex chromosomes separate from each other, the larger passing into one cell and the smaller into another cell; or one or more elements may pass into one cell, while its sister cell receives none or a smaller number. The details vary, but the general

result is the same, namely, an uneven distribution of chromosomes to different sex cells, indicating clearly a separation of entire chromosomes from one another in maturation, and the production of different kinds of sex cells as a result thereof. Now when a sperm carrying a larger number of chromosomes, or a larger member of an unequal pair, unites with an egg, the resulting offspring is a female; while those sperms which carry fewer or smaller chromosomes, upon fertilizing an egg, give rise to males.

In most cases studied thus far the differential divisions occur in the male, the sperm being of two classes, male and female producing; but in a few animals, notably birds, moths and butterflies, the eggs are of two classes and sex determination occurs in the female.

While the greatest mass of evidence available thus far indicates that sex is predetermined in the fertilized egg, there is some recent work which does not apparently agree with this theory. A consideration of this evidence however may best be deferred to a later chapter.

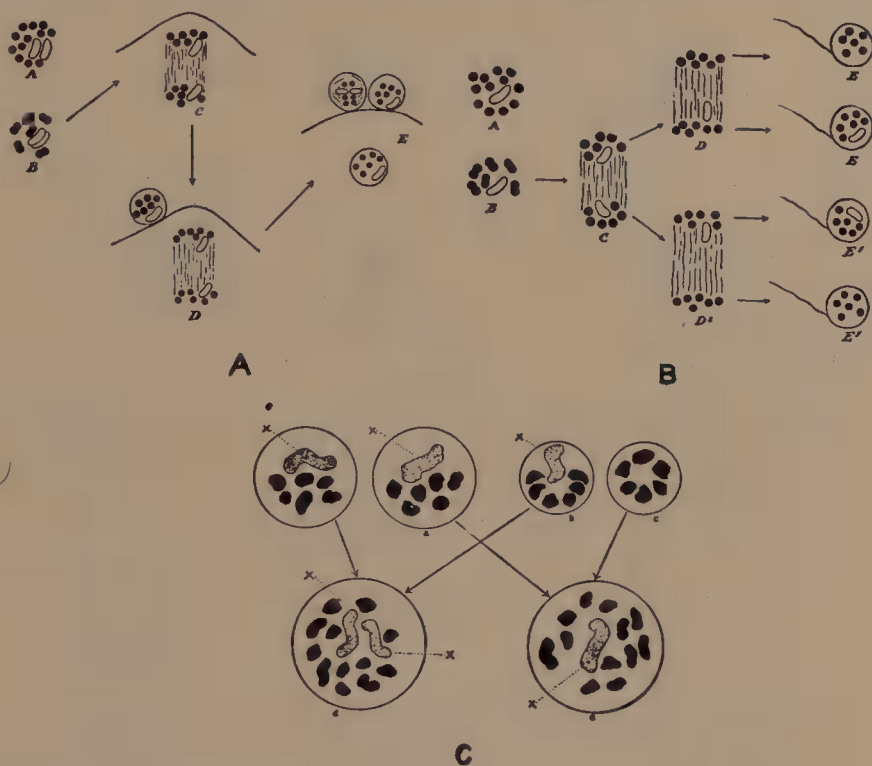
There are also two sexual conditions of more or less common occurrence in plants and animals, which are difficult to explain on the basis of sex chromosomes. One of these, hermaphroditism, is of very general occurrence in plants and certain groups of animals; and the other, gynandromorphism, occurs occasionally in animals. In the former case both sex glands are normally present in the same animal; in the latter varying conditions of the glands occur, sometimes male, sometimes female, sometimes both are present, while externally the body may be of different sexes on opposite sides, or opposite ends, or one-fourth may differ from the remaining three-fourths; in fact, almost any mosaic of external sex characters may occur.

Hermaphroditism is characteristic of most worms, and some molluscs, and occurs occasionally elsewhere. In vertebrates it is rare, being characteristic only of the hagfish (*Myxine*). In mammals true hermaphroditism is not known, so-called hermaphrodites having only the external sex organs hermaphroditic. Various hypotheses have been advanced to bring these conditions into line with the chromosome hypothesis, but thus far without any marked degree of success.

By far the most valuable contribution of recent years to the chromosome theory of inheritance is the work of Morgan and his students at Columbia on the fruit fly, *Drosophila*. By a combination of breeding and cytological studies they have carried this theory almost to the point of fact. *Drosophila* is a little fly, about half the size of the ordinary house fly, which breeds abundantly in decaying fruit and vegetables,

and may be reared *ad libitum* on ripe bananas to which a little yeast has been added. The fly has many variable characters which are well marked and readily Mendelized. The chromosomes also are well defined, so that it furnishes an exceptionally good subject for studies of this character.

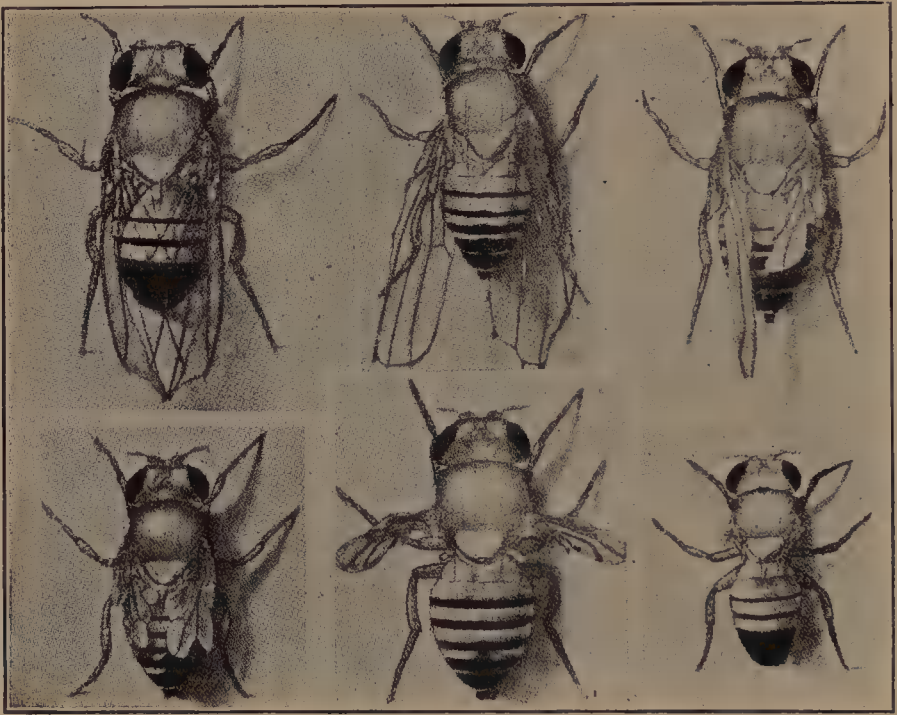
The fruit fly has typically four pairs of chromosomes, and thus far more than 400 distinct characters have been found. Now if these characters has each its determiner in one of the chromosomes, it is obvious that each chromosome must



DIAGRAMS ILLUSTRATING THE DISTRIBUTION OF THE SEX CHROMOSOMES AT MATURATION

A, in the female; B, in the male; C, the resulting possible combinations in fertilization. A and B from Morgan, "Heredity and Sex," by permission of the Columbia University Press; C from Loeb, after Wilson.

carry a large number of characters. That being so, all those characters which are lodged in one chromosome should be inherited as a unit. And that is precisely what happens in many cases, giving rise to the phenomenon known as "linkage." One of the best known examples of this is shown by certain sex-linked (sometimes incorrectly called "sex-limited" characters.)

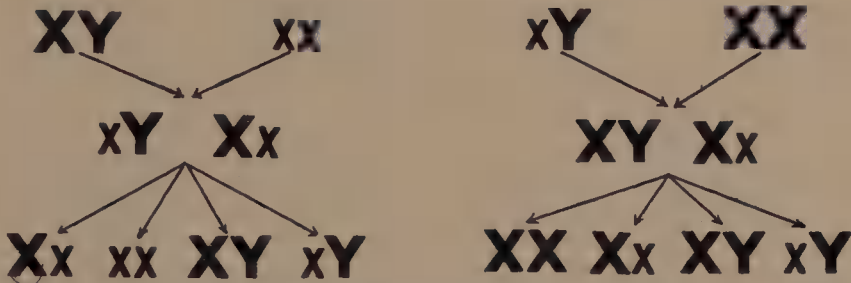


FRUIT FLIES

The two upper figures show the male (right) and female (left) of the fruit fly. The six lower figures show some of its 200 and more mutations, some of the most striking of which are shown by the wings. Note the wingless individual in the lower right-hand corner, and the one with asymmetrical wings just above. By their extensive studies of this humble insect, Professor Morgan and his students have added vastly to our knowledge of the laws of inheritance, which hold true not only for lower animals, but for man himself. After Morgan, "Heredity and Sex,"

By permission of the Columbia University Press.

Usually the fruit fly has red eyes, but occasional individuals occur with white eyes. If a red-eyed male be mated with a white-eyed female the offspring will be of two classes of approximately equal numbers, namely, red-eyed females and white-eyed males. If now the first generation be inbred, four classes will appear in the second generation, of approximately equal numbers each, namely, white-eyed and red-eyed males and females. If the reciprocal cross be made, i. e., white-eyed males by red-eyed females, the results will differ depending upon the purity or impurity of the mother in respect to eye color (i. e., whether or not she carries the white-eye color latent). In the former case (the mother pure red) the first generation will all have red eyes, while the second generation,



DIAGRAMS REPRESENTING THE RÔLE OF THE CHROMOSOMES IN DETERMINING SEX AND EYE COLOR IN THE FRUIT FLY

The female of this fly carries a pair of chromosomes, represented by **XX** or **xx** in the diagrams, and the male a pair differing in respect to one member, thus represented as **XY** or **xY**. The factor for red eye color is represented as carried by **X**. Thus a red-eyed female has the formula **XX** or **Xx** and a white-eyed female **xx**, while red-eyed and white-eyed males are respectively **XY** and **xY**. In the right-hand diagram is shown a mating between a white-eyed male and a red-eyed female, all of the offspring of which are red-eyed. If these are mated with each other, four kinds of offspring result, which are shown in the third row, all the females having red eyes, while half the males have white eyes. The reciprocal cross and its results are shown in the left-hand diagram.

resulting from inbreeding the former, will have red and white eyes in the ratio of three to one. In the latter case (the mother red-eyed with white latent) the results will be the same as those obtained by inbreeding the first generation of the red-eyed male by the white-eyed female cross.

Sex in the fruit fly appears to be determined by a pair of chromosomes, which differ slightly in form and size from the others. This pair is called the **XX** pair in the female and the **XY** pair in the male.

The results of the crosses above described can be most readily explained by assuming that one of the X chromosomes carries the determiner for red eye color and another X the determiner for white. They are shown graphically in the accompanying diagrams, in which the chromosomes carrying the determiner for red eyes are shown as capitals, and those carrying the white eye determiner as small letters.

Many other cases of sex-linked inheritance occur in animals, notably in moths, fish, birds and mammals, including man. In the latter, color blindness and hæmophilia (imperfect clotting of the blood causing continuous flow from wounds) are examples, although the manner of inheritance here is slightly different than that of eye color in the fruit fly.

While the phenomena of linkage are clearly shown in the fruit fly, not only in the eye color but also in color of wings and body, size of wings, etc., the linkage in many cases is imperfect, some of the combinations of characters in the offspring being different from those shown by the parents.

Some fruit flies have vestigial wings and black bodies, while the ordinary type has long gray wings and a light yellow body, banded with black on the abdomen. Black body and vestigial wings tend to stay together in inheritance, indicating that their determiners are both lodged in the same chromosome. But there are some exceptions to this rule. If a black fly with vestigial wings be crossed with one having long gray wings, the offspring will all have long gray wings, this type dominating the former. If now we "back cross" these offspring with the black vestigial parent, we obtain a curious result. If on the one hand we back cross a hybrid male with a black vestigial female, we obtain only black vestigial and gray long flies. The characters have "stuck together," coming out of the cross in the same combination in which they entered it. The linkage is perfect and the evidence is strong that the determiners for the characters tested are lodged in the same chromosome (black vestigial in one, gray long in another), which retains its identity throughout the maturation and fertilization processes. But if, on the other hand, we back cross a female hybrid and a black vestigial male we obtain a very different result; namely, 41.5% of black vestigial and gray long offspring respectively, and 8.5% of black long and gray vestigial. In other words, some of the characters have become mixed in the shuffle and the cards are not dealt "according to Hoyle."

Is such a result a fatal blow to the chromosome hypothesis? On the contrary it furnishes indirectly one of the strongest evidences in its favor.

We have seen above that the chromosomes pair with one:

another in maturation and then separate in the reduction division, so that different germ cells receive different contributions. We have not however considered how the chromosomes pair, whether end to end, or side by side. Much dispute has arisen over this question, which is probably due to the occurrence of different methods in different species. In some cases at least there is definite evidence of a side by side conjugation or "parasynapsis," and in some of these it has been shown that the chromosomes do not lie parallel but wind about one another, forming a more or less twisted braid. When this occurs it is probable, although not definitely proven, that in separating the chromosomes do not unwind but rather pull apart irrespective of the twist, so that a part of one chromosome may now be switched over into another chromosome and *vice versa*. This phenomenon of "crossing over" as it is called, would readily explain the 8.5% of gray vestigial and black long flies obtained in the last experiment; for if the chromosomes carrying the black vestigial and gray long determiners were occasionally to wind about each other and then separate without untwisting the determiners would be apt to get mixed up and find themselves in the wrong pews, so to speak. Why this should occur only in the female and not in the male is a problem. Possibly more extensive experiments would show it to occur in the male also. However, the lack of cross-overs in the male of another species of *Drosophila* (*viriles*) suggest that it is a constant feature of this genus.

Now if this explanation of crossing over be correct, we should expect those characters to cross over most frequently, the loci of whose determiners in the chromosomes are most widely separated, for in the twisting, points at either end of a pair of chromosomes would be more apt to interchange places from one chromosome to the other, than closely adjoining points. And as a matter of fact, great differences do exist in the amount of crossing over between different characters. On the basis of these differences Morgan and his students have made a plan of the chromosomes, locating with a high degree of probability in tiny threads of protoplasm, possibly the diameter of the finest filament of a spider's web, the determiners of more than two hundred characters already studied in the fruit fly.

The fact that all these characters fall into four groups in respect to their linkages, thus corresponding to the four pairs of chromosomes in the fruit fly; and further, that the calculated separation between the extremes in each series, based upon the frequency of the cross-overs, corresponds to the relative lengths of the chromosomes, is very strong addi-

tional evidence for the chromosome hypothesis as outlined above.

In the course of their experiments the students of the fruit fly were suddenly confronted with an unexpected, and at first sight unexplainable case, which seemingly set the chromosome hypothesis on its head. As already explained, if a pure



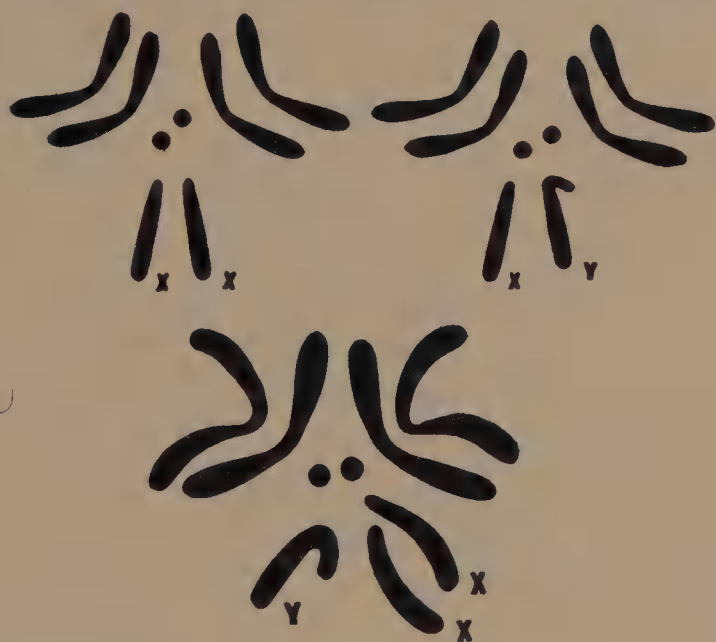
CHROMOSOME MAP SHOWING DISTRIBUTION OF LINKED CHARACTERS IN THE FRUIT FLY

After Morgan, "Heredity and Sex."

By permission of the Columbia University Press.

white-eyed female be mated to a red-eyed male, red-eyed daughters and white-eyed sons in approximately equal numbers are the result. But in one set of experiments this cross produced, in addition to the expected classes of offspring, about 2.5% of white-eyed females and an equal number of red-eyed males. Such a result is readily explainable however on the assumption that the two X chromosomes of the

female stick together in the reduction division, so that one class of eggs receives two X and the other none. A detailed analysis of all the possible combinations resulting from such a case is rather too complicated for consideration here. Suffice it to say that the unexpected class of white-eyed females could be obtained by the fertilization of an XX egg by a Y sperm, and that of red-eyed males by the union of an egg lacking an X with an X sperm (the X being the important chromosome in sex determination, the Y apparently



DIAGRAMMATIC REPRESENTATION OF THE CHROMOSOMES OF THE
FRUIT FLY

The female (left) and male (right). The chromosomes are shown in pairs, the sex pairs being indicated by XX (female) and XY (male) respectively. In the lower figure is shown the peculiar case of a female carrying 2 X and 1 Y, owing to the failure of the 2 X to separate from each other in the ripening divisions of the egg. This condition explains certain unusual results found by Morgan and his students in breeding these flies for eye color. After Morgan *et al.*

non-functional in this connection, 2 X giving a female and 1 X a male). It is also possible theoretically to obtain a female with four sex chromosomes, 2 Xs and 2 Ys. Not only can the unusual breeding results be explained theoretically in this manner, but cytological research shows that such cases actually occur, some exceptional females having been found which contained one or two Y chromosomes in addition to the usual XX.

While there are some objections to the chromosome theory, and while it as yet has only the status of a theory, it nevertheless serves better than any other to explain the observed results of Mendelian inheritance. To what extent the cytoplasm shares with the chromatin the rôle of determination, and whether all the characters of living things, or only the more superficial are determined by the latter, cannot at present be said.

In this tiny workshop of the cell wonderful things are taking place. Here is recorded the history of the past, and here is meted out the fate of generations yet unborn.

CHAPTER VIII

Experimental biology continued. Influence of environment in determining the development of organisms. Effects of temperature, light, moisture, chemicals and food upon the form of animals and plants. The control of sex.

And what of the development of this marvelous cell? What hand guides the growth of the future organism in all its wonderful detail from this apparently simple, but unspeakably complex drop of protoplasm? Is it predestined, or is it plastic, to be molded by the experimenter at his will? These two possibilities are in no wise incompatible with each other. While the pattern of the cloth may be fixed, the form of the garment to be shaped therefrom is as variable as the caprice of fashion. Nor can the former be permanently fixed, unless evolution is a myth.

As we have already seen in Mendelian inheritance the character determiners are apparently distributed according to the laws of chance. But there is evidence showing that this distribution can, to some extent at least, be controlled.

If the female fruit fly be exposed to temperatures ranging from 50° to 86° C. at a certain period during the maturation of her germ cells, it is found that the amount of crossing over between two factors may be increased by more than 100%. That external factors may profoundly influence Mendelian results has been clearly shown by Tower. The genus *Leptinotarsa*, of which the common potato beetle is a member, shows several color variations, which have been designated as species. When the female *L. signaticollis* is crossed with the male *L. diversa* at an average temperature of 75°-79° F. and a relative humidity of 75%, the hybrid offspring fall into two distinct groups of practically equal numbers, one of them indistinguishable from the mother and the other intermediate between the two parents. The former group breeds true for several generations; but the latter when inbred give the typical Mendelian ratio of 1 *signaticollis*, 2 intermediate and 1 *diversa*, the first and last of which breed true, but the second continues to split up in further breeding, into the two parent and the intermediate types. If however the crossing be done at an average temperature of 50° to 75°

F. and relative humidity of 50-80% only the intermediate form is obtained. Not only are these results given by different pairs of closely related individuals, brothers and sisters, but the same pair when mated under different conditions give different results.

While Mendelian characters are evidently represented by definite determiners in the germ cells, there is abundant evidence that the development of these characters can be controlled by environment. There is a sex-linked dominant character in *Drosophila* known as abnormal abdomen, in which the usual black bands upon the abdomen are irregular and broken and may even be absent. That this character depends on the type of food (whether wet or dry) for its development may be shown by the following experiment. If an abnormal male be crossed with a normal female and the larvæ fed on wet food, the daughters will be abnormal and the sons normal; but if the food be dry, both daughters and sons will be normal. From these latter daughters however abnormal offspring may be obtained if the conditions are favorable, showing that the determiner for abnormality is present, regardless of external conditions, but the development of the character itself is dependent upon this latter factor.

The influence of environment in determining the form of the individual animal or plant is so well known as to be commonplace. Food, temperature, pressure, moisture, chemicals, radiation may, one or more, so profoundly change the development of an organism that two differently cultured individuals may not be recognizable as members of the same species.

The effect of environment on individual development is perhaps nowhere more strikingly shown than in many species of mountain plants, which range from the low moist valleys to the high arid slopes above timber line. Seeds of the same species will produce in the former situation tall stemmed plants, with large thin leaves, small roots and pale flowers, which require from two to three months to mature seed; while in the latter environment they develop plants with short stems, small, thick leaves, and bright colored flowers, which set seed within a few weeks after the blossoms open; all of which, possibly excepting the flower color, are adaptations to their different environments.

A test of the influence of the environment upon plants has been made by the Department of Botanical Research of the Carnegie Institution, by the introduction of various species of plants into areas having very different climates, in the hot dry desert at Tucson, Arizona, in the cool climate of the neighboring mountains, and in the cool moist climate of the



THE INFLUENCE OF ENVIRONMENT ON PLANTS

A, *Campanula* from 8,300 feet altitude at the left and one from 14,100 feet at right. B, from left to right, gentians growing in shade and sunlight at 8,300 feet altitude, and alpine form from 13,000 feet. C, at the left, alpine form, at the center, sunlight, and at the right, shade forms of *Androsace*. From "Plant Indicators."

Courtesy of Doctor F. E. Clements and the Carnegie Institution.

California Coast near Monterey. A very pretty example of the response of plants to such climatic changes is given by the common poke-weed (*Phytolacca*) of the eastern United States. In California the body of the plant grows well, but the flowers are usually reduced and seed is not formed, while at Tucson, on the contrary, the plant body grows low and prostrate, and flowers and fruit are abundant. There are many other changes also, both of leaf and flower. In this instance at least the variations appear to be temporary and not inherited.

The common water-cress of our eastern ponds and streams, when cultivated out of water, develops enlarged roots, and marked changes in the form of the leaves, the submerged leaves having very narrow, almost thread-like leaflets, while, when grown in the air, the leaflets are broader.

The results of experimental modification of the form of animals are too numerous for full discussion here. Many of them are cited by Darwin in his different books, and the majority of them have been obtained by European workers. The seasonal variations (summer and winter) of certain butterflies can be produced at will by temperature control during the pupa stage. Similarly local varieties (northern and southern) of butterflies can be produced by temperature control during the developing period. Differences of color between the sexes can similarly be controlled. The seasonal changes of arctic birds and mammals are well known, and are supposed to have selective value, either for offense or defense. That these changes are at least secondarily dependent upon temperature was shown by the experience of the arctic explorer Ross with the lemming, or arctic mouse; which when kept in the ship's cabin in winter retained its gray coat, but when put on deck promptly changed to white. The celebrated experiment with the Porto Santo rabbits recorded by Darwin is supposed to illustrate the influence of climate in changing animals. These rabbits are believed to have originated from the progeny of a single female produced on shipboard about 1418 or 19. According to Darwin these rabbits, when examined by him in 1861, showed marked differences from domestic rabbits, being much smaller and differing in the form of the skull and in color. Four years later however under the influence of the English climate, they had resumed the color of the domestic form. Recently however Mr. Gerrit S. Miller of the U. S. National Museum has claimed that the celebrated Porto Santo rabbits are nothing more nor less than the rabbits native to southern Europe. Even if this is so however it does not invalidate Darwin's

observation on the change induced by transferring the rabbits from Porto Santo to England.

Great differences also have been produced in butterflies and moths by changes in the food of the caterpillar, while light, electric and chemical stimuli, etc., show marked effects.

The results of some American workers will now be considered in more detail.

The salamander *Amblystoma* has gills and fins and lives in the water during its larval or axolotl stage. At metamorphosis it loses fins and gills, leaves the water and thereafter lives upon the land. In some cases however metamorphosis does not occur, and sexual maturity appears in the larval form. Although the relationship between the axolotl and some terrestrial form was suspected by Cuvier, it was not discovered until 1865 in the Jardin des Plantes at Paris, when the young of some axolotls gradually lost their gills, their fins disappeared and they came forth upon land to live thenceforward as *Amblystomas*. All the factors controlling the metamorphosis cannot at present be stated with certainty, but apparently a regular but small supply of food as opposed to abundant but irregular feeding tends to prevent metamorphosis. It has been generally supposed that drying up of the water, with consequent lack of oxygen, forced the salamanders to an air-breathing habit and induced metamorphosis. But Powers has shown that the axolotl will metamorphose in abundant and well-aerated water, if its food supply be cut off, and conversely forcing the salamanders out of the water will not induce metamorphosis unless accompanied by a change from an abundant to a meagre diet. His explanation of the control of metamorphosis by nutrition is that, when suddenly deprived of food, the salamanders are forced to live on their own tissues, and that those of gills and fins being the first consumed, causes the reduction of these organs, and induces metamorphosis. His interpretation is supported by the fact that during metamorphosis the animals are generally in a state of semi-starvation.

As is well known, *Amblystoma* is an exceedingly variable animal, and Powers has related these variations in large measure to nutrition. Regular, but moderate amounts of food, produces slender and agile animals, while heavy feeding, on the contrary, produces fat and lazy beasts, which spend most of their time on the bottom of ponds or aquaria. Most marked of all the varieties are certain animals of large size, very broad heads and frequently emaciated appearance, which result from cannibalism. Axolotls ordinarily feed upon microscopic life in the water such as larvæ of insects,

etc., but occasionally they take to preying upon each other, oftentimes with results fatal alike to cannibal and to prey. Powers records his observations of some cannibals as follows:

"It was curious that in every instance where two or more of the cannibals were placed at close quarters, even though other larvæ were present, the result was the destruction of one or both of the cannibals, while the others frequently remained unharmed. This result is not due to the natural enmity of competitors or to a wise foresight with regard to a limited food supply, but purely to the strongly modified reactions of the cannibals themselves. While an ordinary larva instinctively avoids close contact with another, and beats the most precipitate retreat at the merest touch of cannibalistic jaws, the possessors of these weapons themselves are apparently wholly divested of this innate fear. Unless decidedly hungry they lie sluggishly at the bottom, either ignoring the chance contacts of other specimens, or savagely nabbing the intruder. The violence and instantaneousness of their occasional movements contrast strongly with their sluggish inactivity between whiles. Even complete satiety does not usually check their savage attacks, provided that the proper stimulus is offered; the prey is then seized and held some time or half swallowed, to be then as quickly rejected by a sudden jerk much like the one by which it was seized. Thus it is that cannibals in close proximity almost invariably prove each other's undoing, the swallower frequently succumbing as well as the swallowed. Even when taken in the reservoir, not a few of the broad-heads were sadly bitten or abraded, some having been, it would seem, nearly swallowed before meeting with the resistance, no doubt, of some friend who had just gone before."¹

Not only may ordinary individuals be induced to assume the cannibalistic habit, with resultant change of shape, but cannibals may occasionally be reformed and made to resume the ordinary shape. Obviously the larval form is very plastic and readily amenable to the influence of habit. The greatly exaggerated head with its wide gape is clearly the result of swallowing large prey, while the emaciation of other parts of the body, especially gills and legs, Powers ascribes to the "energy—absorbed in the heroic efforts of ingestion" and the nourishment required for the excessive development of head, digestive tract and body length.

The change of plumage in birds in the spring and fall months is a commonplace, but none the less wonderful phenomenon, a satisfactory explanation for which has not yet

¹"Studies from the Zoological Laboratory," University of Nebraska, Vol. IV, pp. 57-58.

been given. One of the most striking of these color changes occurs in the male scarlet tanager, which during the breeding season wears a uniform of brilliant scarlet with black wings; after which he assumes a dull olive drab like the female, which he wears during the winter, resuming his brilliant garb in spring. Another bird with a pronounced difference between summer and winter plumage is the male bobolink. We hail with joy his return to our northern fields in spring, with his bright livery of black, buff and cream, and his ringing, cheery song. In the fall, when in his dull drab coat



EFFECT OF DIET ON BODY FORM IN AMBLYSTOMA

Fig. 1, young cannibal after full meal. Fig. 2, typical larva. Figs. 3-5, young cannibals. Fig. 6, normal larva, typical of the ordinary specimens among which the cannibals were found. From Powers, "Morphological Variation and its Causes in *Amblystoma tigrinum*," Studies from the Zoölogical Laboratory of the University of Nebraska, Vol. IV, No. 71.

he gathers in flocks of thousands upon our marshes, we shoot him as the plump little "reed bird"; while over the rice fields of the Carolinas, upon his return from his summer sojourn in the North, he meets an even worse reception from the rice grower as his inveterate enemy, the "rice bird."

Immediately following the breeding season, i. e., at the time of the fall molt, birds are usually in poor condition both in respect to feathers and flesh. Some male tanagers and bobolinks in the New York Zoölogical Gardens were prevented from breeding for one season, during which time they remained in full song and excellent physical condition and retained their full breeding plumage. About a month previous

to the time of the fall molt the birds were put in a darkened room and their food supply slightly increased. On this regimen the birds grew fat and lazy and ceased to sing. Most of them passed the winter thus in full summer plumage, but one of the tanagers molted into the winter plumage as a result of a sudden change of temperature. In the spring the birds were brought under normal conditions again and promptly molted into the spring plumage, the winter molt having been entirely suppressed, a beautiful example of environmental control of an hereditary trait.



THE SCARLET TANAGER, MALE AND FEMALE (Right)

A striking example of sexual difference in birds. The winter dress of the male is similar to that of the female. From Cooke, "Bird Migration," in Bulletin Bureau Biological Survey.

THE BOBOLINK (Left)

A bird of many aliases, admired in the North, detested in the South. From a drawing by Louis Agassiz Fuertes in Cooke, "Bird Migration," Bulletin Bureau Biological Survey.

The effects of light on the color of animals are clearly marked in some instances, and in others seemingly negligible. The typical fauna of caves comprises animals, which have little or no pigment, and either partly or wholly degenerate eyes. The amphipod *Eucrangonyx gracilis* occurs both in the open and in caves. In the latter situation its eyes alone are pigmented, while in the former, other parts of the body

are pigmented also. If the young of specimens living in the open are kept in the dark during development, the pigment is more or less absent. Different species of salamanders show differing results when reared in artificial caves; in some there is very slight reduction of pigment and in others this reduction is temporarily almost complete. These latter however may develop the normal amount of pigment at metamorphosis. *Vice versa*, cave animals lacking pigment may or may not develop pigment, when reared in the light. Possibly the less responsive types are those which have lived longest in their respective habitats. However the fact that there is considerable individual variation in this respect suggests that some other factor is involved.

An interesting adaptation of certain cave animals is their greater sensitiveness to tactile than to light stimuli as compared with their free-living relatives.

Animals respond readily to chemical treatment. Some of the most noted experiments along this line are those of Stockard in the production of Cyclopean fish. By treating developing minnows with magnesium salts, alcohol, chloroform, etc., he has replaced the paired eyes with an unpaired median one resembling that of the fabled Cyclops, and similar results have been obtained by McClendon and Werber. Not only may Cyclopean monsters be formed by chemical treatment, but deformities of many kinds. Eye deformities may range all the way from various stages in the approach and fusion of the eyes, through Cyclopean eyes, to no eyes at all. The eyes may be rudimentary in size and displaced dorsally; or there may be inequality of the two eyes, leading to the absence of one of them. An eye may even be developed entirely outside the body of the embryo, on the surface of the yolk sack. Abnormalities of the eyes are usually accompanied by those of nose and mouth, which are frequently drawn out into a snout-like projection. In cases in which one eye is lacking its place may occasionally be taken by the mouth. The nasal pits may fuse into one, and the same may be true of the ears. Or these latter may be enormously swollen, or on the contrary exceedingly small, when one or more of the semi-circular canals may be defective or lacking. Partial embryos may occur, or the parts of the embryo may develop separately, as in the case of a yolk sack eye, already mentioned. In fact every imaginable deformity may be produced by chemical treatment, from very slight defects to those so great that the resulting creature is merely a formless mass of living matter.

Abnormal development may sometimes run a more orderly course and produce symmetrical, relatively perfect creatures

which Professor Wilder calls "cosmobia." Thus in man there exists a whole series of duplicities from a slight cleft of the spinal cord to those in which the cord is doubled for its entire length and is more or less rudimentary. The doubling process may go further, resulting in a double-headed monster, or one with two heads and four arms. Or if the process proceed in the reverse direction a single body and head may possess two pairs of legs; while if the doubling process occur at both ends simultaneously "Siamese twins" result; until finally if the body be completely separated "identical twins"



CYCLOPEAN FISH

Produced by treatment with magnesium salts. From Stockard, in "Journal Experimental Zoölogy," Vol. 6. Mouth; yolk sack.

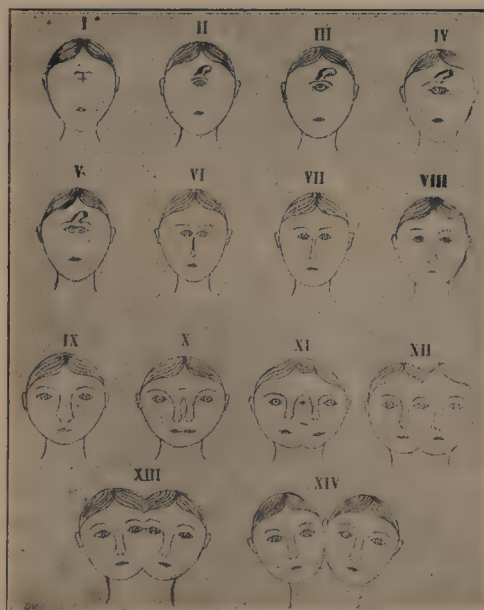
occur, which are always of the same sex, and resemble each other as closely as the proverbial "two peas in a pod."

The experiments on fish embryos strongly support the theory of Mall, that monstrosities in man are due to diseased conditions in the mother's uterus, with resultant metabolic disturbances and the formation of toxins in the embryo and fetus.

We have seen in the last chapter that our present evidence very strongly indicates that sex is predetermined in the egg, so that most of the supposed instances of its artificial control are at the present time of historical interest only. One of the most popular theories of sex determination ascribes to food a sex determining influence. Experiments of this nature have



A HUMAN TWIN MONSTER



TYPES OF HUMAN FACES

From the single "Cyclopean eye" type (I-V) through normal (VI-IX) to duplicate (X-XIV), showing intergradations. From Wilder, "The Morphology of Cosmobia," "American Journal of Anatomy," Vol. 8.

been performed on insects, frogs, birds and mammals. Better nutrition is supposed to produce more females and *vice versa*. In this way the attempt has been made to explain the increase in males in France during the Napoleonic wars. One observer has cited data showing that among the nobility of Sweden the proportion of males to females is 98-100, while among the clergy the ratio is 108.6-100. Another has shown on the contrary that in London the more well-to-do have a larger percentage of sons than daughters. Temperature, age of parents and ripeness of eggs are other popular factors in sex determination. But one of the most naïve of recent theories supposes that there is a regular alternation of male



A HUMAN "MONSTER"

Courtesy of Dr. Geo. L. Streeter.

and female producing ova in man, the former coming from the right, and the latter from the left ovary, and that sex might be determined by the position of the prospective mother, whether lying on her right or left side.

Extensive experiments have been conducted on the influence of external factors in determining the sex cycle in parthenogenetic animals. The most familiar example of this type is the bee, in which the unfertilized egg gives rise to a male (drone) and the fertilized to a female (queen) or an undeveloped female (worker). Here sex depends upon the act of fertilization, and is probably determined by the chromosomes, which differ in number in the two sexes. The influence of food in controlling development is here most beautifully

shown, for the fertilized egg becomes either a queen or a worker, according to the kind of food which it receives.

In other parthenogenetic forms the sex relations are not so clear. Among the fresh water Crustacea the daphnids present a well-known example of parthenogenesis. When the daphnids appear in spring or summer only females are found. They lay thin-shelled eggs which develop without fertilization into other females which in turn lay parthenogenetic eggs, and so the story goes for several generations; when suddenly, males make their appearance, together with the "winter" or "resting" eggs, which are fertilized, and surrounded by a thick shell, in which they pass the winter inactive in the ooze at the bottom of the water. With the advent of warm weather the following year these eggs hatch, giving rise to



MOLTED SKIN AND LIBERATED EGG CASE OF A DAPHNID

Photo by Lloyd, from Needham and Lloyd's "Life of Inland Waters," Comstock Publishing Company.

parthenogenetic females, which repeat the story. The time of appearance of males varies in different species. In some it appears to be correlated with the lowered temperature of autumn, and in others with the drying up of the pools in which the animals live. A similar life history is presented by the rotifers, or "wheel animalcules," so called from the circle of vibrating cilia at the anterior end.

The group of nematodes or thread worms present some curious modifications of the sex cycle. Some of these are parasitic, others are free-living and yet others present a so-called "alternation of generations" in which one generation lives parasitically and the other free. Moreover some are hermaphroditic, others bi-sexual. Among the bi-sexual, free-living forms, parthenogenesis is of common occurrence, having gone so far that in one species, males occur only in the ratio of 13 to 100,000 females, while in others they have not as

yet been discovered. Furthermore in some cases the males have lost the sexual instinct and the females have partly developed hermaphroditism, producing sperms, which enter the eggs but take no further part in their development, the latter developing by parthenogenesis.

The principal American workers on control of the sexual cycle in parthenogenetic forms have been Shull and Whitney. It has been claimed by some European zoölogists that temperature or food are controlling factors in the production of males in daphnids and rotifers. The influence of the former factor is seemingly borne out by the occurrence in nature of differences in the cycle in different races of the same species. Thus *Chydorus sphaericus*, a European daphnid, reproduces both parthenogenetically and sexually in the lowlands of central Europe, while in the mountains, reproduction is said to be exclusively parthenogenetic. The influence of these factors is denied by the former workers. They have demonstrated however a marked influence of the purity of the culture medium on production of males, the proportion of males to females in *Hydatina senta* being greater the more the culture medium was diluted with spring water. Possibly the controlling factor here was the relative acidity of the medium, for Banta has shown the influence of this factor in controlling the production of males in daphnids. It has been argued that these experiments have nothing to do with sex control, that all they prove is the possibility of shifting one way or another the time of appearance of males, in an alternating sex cycle, in support of which argument is presented the fact that the *same* mother will produce males or females from the *same* eggs, depending on whether or not these are fertilized, similarly to the case of the bee mentioned above. But is not this begging the question, for what is it that determines the appearance of the males in the first place? The evidence indicates that it is an external factor, and in so far as this is true we certainly are controlling sex.

There is some recent work by Riddle which indicates that sex in birds is a question of metabolism, males arising from germ cells of higher metabolism, larger water content and less fat and phosphatides. Riddle claims the sex may be controlled by controlling these factors in spite of the sex chromosomes, which are "but a sign or index, not an efficient cause of sex." His results, while seemingly conclusive, need to be extended, and correlated with those of the cytologists before any certain conclusions can be drawn however.

The conditions found in some of the Crustacea and geophy-reans indicate that sex is not a predetermined, unchangeable condition. Some of the parasitic isopods are first males

and later become females. In the sand hopper (*Orchestia*) occur alternate periods of maleness and (partial) femaleness, while in *Bonellia*, one of the gephyrean worms, the larva develops into a male or female, depending upon whether it lives attached or free. While sex appears, in many cases at least, to be predetermined in the egg, it would not be safe at present to say that this predetermination was in all cases irrevocable.

A curious condition has been discovered by Banta in some of the daphnids (*Daphnia* and *Simocephalus*) in the form of "sex-intergrades." In these animals the sexes are readily distinguishable externally by several secondary sexual characters, such as size and form of body and appendages, hairiness of ventral surface, etc. Banta has found a complete series of intergrades, ranging from normal males on the one hand, through males with one or more of the secondary characters of the female, to hermaphrodites and females with certain secondary male characters, and finally to normal females on the other. A similar condition has been found by Goldschmidt in the gypsy moth, and by Stout in the common plantain weed. How far these results agree with the chromosome hypothesis of sex determination is very much "up in the air" at present.

Reference has already been made to *Hydra*, a name classic in biology as in mythology. *Hydra* may reproduce either by simple division of its body into two parts, by forming buds which develop into new *Hydras* and are then pinched off the parent stock, or by developing sex organs followed by fertilization. Whitney has shown that the appearance of sex organs can be controlled by external factors, such as temperature and food. Thus, if *Hydra* be kept for a time at a low temperature, and the temperature be then raised and the animal starved, testes and ovaries develop. Sexual reproduction in lower plants (i. e., *Vaucheria*, etc.) has also been controlled by external factors. These latter experiments however deal with the control of sexual, as distinct from asexual reproduction, and not with the determination of sex itself.

In the foregoing pages we have sketched very briefly a few of the facts bearing upon the relative rôles played by heredity and environment in the development of the organism. Needless to say the two factors are in no sense antagonistic or mutually exclusive, but both work together in fashioning the final product. The inheritance of the organism may be compared to the molten metal; the environment, the mold in which the metal is cast.

CHAPTER IX

Experimental biology continued. The factors of evolution: natural selection, mutation, orthogenesis, isolation, inheritance of acquired characters. Experimental modification of the germ cells.

The search for the beginnings of things was one of the earliest tasks of the human mind. Man, like a little child, with a "why?" ever present on its tongue, has never ceased to ask the questions, "Whence came I, and whither am I bound?" With the latter question science, with her present limitations of time and space, has naught to do, but the latter ever has been, and perchance ever will be the focal spot of human thought. Strange and curious are the many fancies with which primitive philosophy has invested the problem, and in spite of all the wonderful achievements of modern science she is still but playing with the pebbles on the seashore. We smile complacently as we read of the fat turtle of the Iroquois philosopher, which, waddling along one hot summer day, found his shell too great a burden, and throwing it off became a man; or of the crude philosophy of the early Greeks who imagined a fish coming upon land, bursting its horny capsule and stepping forth a man; or yet of the old French philosopher who related a tale of a wonderful tree, whose leaves, falling on the one hand upon water, gave rise to fish, and on the other upon land, took wings and flew away as birds, naïvely remarking that while this magical tree was not, to be sure, to be seen in France, yet it was said to be common in Scotland, a land, which to the reader of those days, was a terra incognita. And we shake our heads learnedly as we talk today of "fortuitous variation," "internal perfecting principles," "entelechies" or "orthogenetic evolution." But when, in the language of the street, we "get down to brass tacks" are we really any wiser than our forbears? And yet the denser our ignorance the more alluring becomes the field of research, while the frontiers of knowledge ever recede as we approach, impelled by the primeval instinct to explore.

While the theory of evolution has become axiomatic among thinking men of every school, the ways and means of evolution are as great a bone of contention as ever. It is but nat-

ural therefore that the factors of evolution and heredity, for the two processes are of necessity indissolubly united, should be the center of modern biology.

The success of Darwin in establishing the theory of evolution was due primarily to his explanation, by the theory of natural selection, of a reasonable process by which evolution could be effected, and his support of this theory with a vast array of facts, and of logical arguments deduced therefrom. And yet the theory of natural selection or survival of the fittest antedates Darwin by more than two thousand years.

The Greek poet-musician-naturalist, Empedocles, who lived in the fifth century before Christ, fancied living creatures as arising from the four elements—earth, air, fire and water, under the action of the forces of love and hate. The animals first formed, “appeared, not as complete individuals, but as parts of individuals,—heads without necks, arms without shoulders, eyes without their sockets. As a result of the triumph of love over hate, these parts began to seek each other and unite, but purely fortuitously. Thus out of this confused play of bodies, all kinds of accidental and extraordinary beings arose,—animals with the heads of men, and men with the heads of animals, even with double chests and heads like those of the guests in the Feast of Aristophanes. But these unnatural products soon became extinct, because they were not capable of propagation.”¹

These crude ideas of Empedocles are interesting historically because they show how early the survival idea arose in man’s mind. By many other writers also, previous to Darwin, this idea was expressed, notably Hume, Buffon, Kant and St. Hilaire, and when Darwin’s thesis itself was presented to the world it appeared as two papers published simultaneously in the *Journal of the Linnean Society* by himself and Alfred Russell Wallace.

In spite of the splendid exposition given by Darwin of the theory of natural selection, and its very general acceptance by scientific men of a few decades ago, the pendulum of scientific thought is swinging today in the opposite direction, and the consensus of opinion is distinctly adverse to the acceptance of the theory in all its important points.

Before considering the experimental work which has largely induced this reversal of opinion, let us see what the essential features of the theory are. Three factors are involved, namely, variation, inheritance, and selection or survival. Let us illustrate their co-operation to produce evolution by a concrete example from Darwin’s “*Origin of Species*.” “The

¹ Osborn, “From the Greeks to Darwin,” p. 38. By permission of the Macmillan Company.

giraffe, by its lofty stature, much elongated neck, fore legs, head and tongue, has its whole frame beautifully adapted for browsing on the higher branches of trees. It can thus obtain food beyond the reach of the other . . . hoofed animals inhabiting the same country, and this must be a great advantage to it during dearths. . . . So under nature with the nascent giraffe, the individuals which were the highest browsers and were able during dearths to reach even an inch or two above the others (variation) will often have been preserved (selection). . . . They will have intercrossed and left offspring, either inheriting the same bodily peculiarities, or with a tendency to vary again in the same manner (inheritance); whilst the individuals, less favored in the same respects, will have been the most liable to perish.”¹

One of the strongest evidences cited by Darwin in support of his theory was that of artificial selection. If man, he said, in a few hundreds or at most thousands of years, could produce, by selection, all the manifold varieties of domestic plants and animals which we know today, why could not Nature, working through the countless ages of biologic time, perform the creative wonders of the past and present kingdoms of animals and plants inhabiting the world? It is difficult however to subject the work of the practical breeder to scientific analysis, based as it is upon purely economic grounds. Furthermore, we have today a mass of information regarding inheritance which was not available to Darwin. Within recent years therefore the problem has been attacked scientifically by a number of workers, the pioneer being the Danish botanist, Johannsen.

If one choose any group of organisms, be they men or be they microbes, and carefully arrange them according to size, he will find that they form a series, with an average and two extremes—a greater and a lesser. If now, on the one hand, the largest individuals, and on the other the smallest, be chosen for breeding, and from their offspring in turn the largest and the smallest be again selected, can finally two new races, a larger and a smaller, be developed? This question forms the crux of the selection theory.

To test it Professor Johannsen of Copenhagen chose at random 12,000 beans and measured the length and breadth of each to obtain an average. From these he chose nineteen, ranging from the largest to the smallest. Breeding these for seven years, and selecting the largest and smallest seeds for each planting, he found that, while the largest beans produced seed larger than the average of the 12,000, and the smallest produced seed smaller than the average, subsequent selection

¹ Pp. 276-7, 6th ed.

availed nothing to increase or decrease the size of each "pure line" as Professor Johannsen called the progeny of his nineteen seeds. "Can a man add one cubit unto his stature," or a bean one millimeter unto its length? Professor Johannsen thinks not.

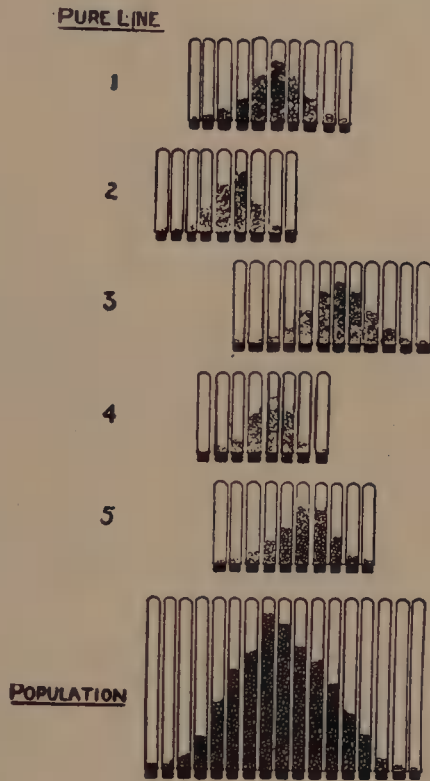


DIAGRAM SHOWING THE EFFECT OF SELECTION UPON A MIXED LOT OF BEANS OR "POPULATION"

If several thousand beans, selected at random, are sorted according to size and placed in test tubes, the lower figure will result; those beans of an average size will be greatest in number, while the larger and smaller sizes will be fewest. If beans from different test tubes be selected for planting the "pure lines" 1, 2, 3, etc. will result. Further breeding of these "pure lines" will not serve to change the average size of the population, selection serving merely to sort out the varieties jumbled together in a mixed "population." From Walter, after Johannsen.

Similar results have been obtained by several American workers, notably Professor Pearl, who, while at the Maine Agricultural Experiment Station, attempted by selection to increase the laying capacity of hens—and failed; and Professor Jennings of Johns Hopkins, who has likewise shown that selection is powerless to change the size of the one-celled animal *Paramecium*.

But the voice of the selectionist is not yet stilled. Perhaps the chief American exponent of the theory has been Professor Castle of Harvard, whose work on hooded rats is well known to all biologists. The hooded rat is a color variety of the common brown rat, with black head and shoulders and a black stripe on the middle of back and tail. By persistent selection of individuals with more black and more white respectively, Castle has obtained individuals ranging all the way from those with a small median stripe of white upon the belly to others with only a small patch of black upon the snout.³

For over twenty years a selection experiment has been conducted at the experiment station at the University of Illinois, which also appears to give strong support to the the-



“HOODED” RATS

Showing the results of experiments by Professor Castle of Harvard in selecting these animals for extent of black and white in the pattern. After Castle & Phillips, “Piebald Rats and Selection,” Carnegie Institution, Publication No. 195.

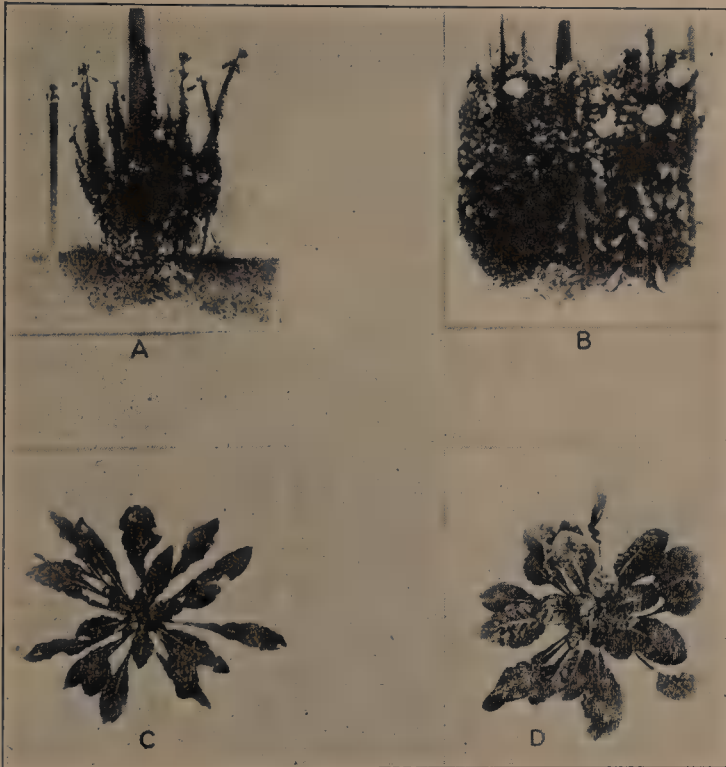
ory. In 1896, Professors Hopkins and Smith began selecting seed from ears of corn which had on the one hand a high, and on the other a low protein content. This continual selection has resulted not only in producing grades of high and low content, but each succeeding year shows on the average a wider divergence in the two grades. Thus, starting in 1896 with an average per cent (in weight of grain) of 10.92 they produced the first year a high grade of 11.10% and a low of 10.55% with a difference of only 0.55%. By gradually increasing steps these figures after twenty years’ selection reached 14.53% for the high, 7.26% for the low and 7.27% for the difference. Similar results were obtained by them in selecting for oil content.

The anti-selectionists however have explained these results as due merely to the sorting out of variations already present in a very mixed stock. A better understanding of the

³ Recently Professor Castle has modified his original contention.

whole question of selection can be had after a discussion of the next factor of evolution, namely mutation.

The mutation theory is not a new one to biologists. A century ago St. Hilaire suggested the origin of birds from reptiles, the first formed bird hatching full-fledged from a reptile's egg. The existence of mutants or "sports" were well known to Darwin, and are cited by him as a source, although a minor one, of evolution. The cases which he gives are how-



MUTATION IN *OENOTHERA*

The original stock *lamarkiana* to the left, *gigas* a mutant to the right. From Castle, "Genetics and Eugenics,"

By permission of Harvard University Press.

ever of a striking and unusual sort. The Ancon ram is one of these. In 1791 a Massachusetts farmer discovered in his flock a ram with short crooked legs and a long body. The thrifty farmer bred from this ram in order to obtain a flock of sheep which could not jump fences, and would thereby save himself much worry, and his sheep dog much exercise. This was the origin of the famous breed of Ancon sheep, which is now however extinct. The merino sheep, a breed having long silky wool, which originated in 1828, is another exam-

ple cited by Darwin. Still other instances are those of hornless cattle, hairless dogs, bob-tailed cats, web-footed chickens and extra-fingered men. These however are exceptional cases; the great mass of mutations, those mainly productive of evolution, are of the minor sort, appreciable only by careful measurement and statistical analysis.

The presentation of the mutation theory in its present form we owe mainly to the Dutch botanist, DeVries. A brief résumé of the latter's work will bring the subject fairly be-



A RUMPLESS FOWL

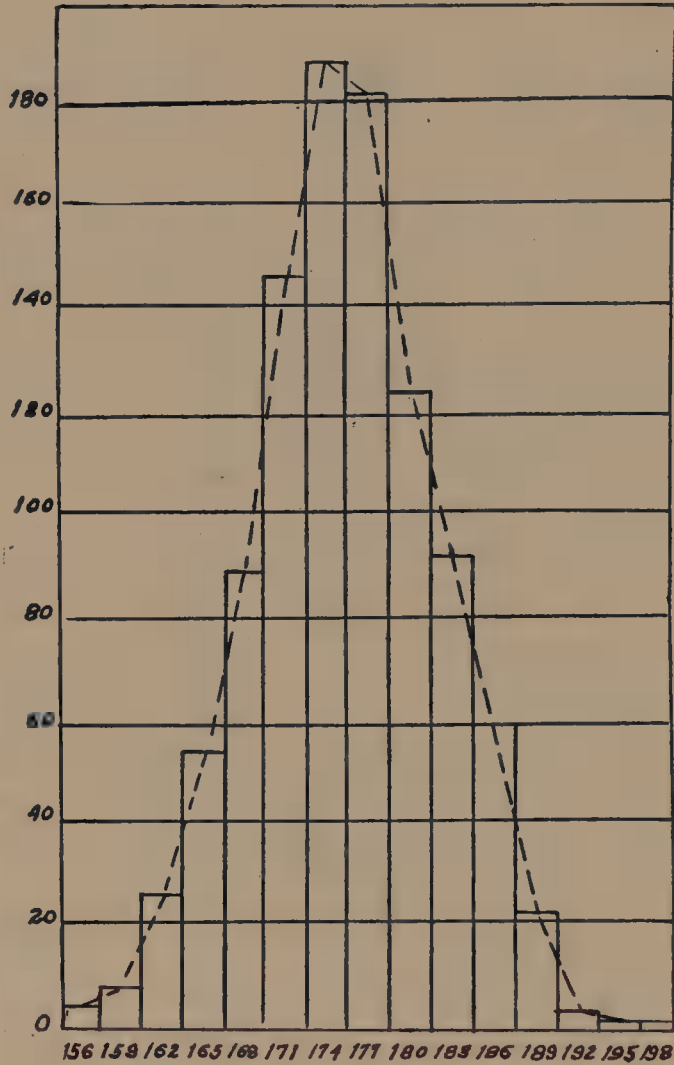
An example of mutation. From Davenport, "Inheritance in Poultry," Carnegie Institution, Publication No. 52.

fore us. Over thirty years ago DeVries found certain well-marked varieties of the evening primrose, a native of America, which had been introduced into Europe and was growing as a weed around the city of Amsterdam. Specimens of these varieties and of the parent species were transplanted in his garden and bred for many years including eight generations, during which time he discovered and recorded over 800 variations from the parent type, whose possessors bred true to themselves. By selection of these variations he was able to produce a large number of distinct types of primrose which he called "elementary species."

Since the publication of DeVries' work on the mutation theory the attention of biologists has been focussed more and more on this factor of species building, and large numbers of cases have been recorded in both animals and plants. These cover the whole gamut of variation and are both qualitative and quantitative in kind. They include variations in color, markings and size; in form; length and number of hairs, bristles, etc.; differences in shape of parts such as leaves of plants, wings of insects, horns of cattle, etc.; differences in habit of plants, whether erect or procumbent, straight or branching, etc.; differences in the number and union of parts, such as syndactylism and polydactylism in man and other animals; differences in presence or absence of parts, such as absence of a tail in cats and chickens; in fact, virtually every character known of either animal or plant is liable at some time or other to show mutation. Mutations vary moreover in size, from the large "sports" already mentioned, down to variations so small that it is mere hair-splitting to attempt to distinguish between them and Darwin's "fortuitous" variations on the basis of size alone.

What distinction then if any can be made between these two classes? Darwin did not attempt to define "fortuitous" variations, but speaks of the term as serving "to acknowledge plainly our ignorance of the cause of each particular variation." His distinction between them and "sports" or mutations was one of size alone. More recently however we have learned to recognize in the small "fortuitous" variations of Darwin two distinct kinds of variability, one of which we call "continuous" or "fluctuating" and the other "discontinuous" or "mutating." If the sizes of any group of organisms, let us say men, be plotted on a chart, as we shall find a point which is called the mode, at which fall a greater number of measurements than at any other, while the remainder graduate to either side of this point until the limits of the series are reached. Such a chart is called a frequency polygon (or curve, if the measurements are sufficiently numerous and close together). Such a chart represents graphically "fluctuating" variation, the variations falling indiscriminately on either side of the mode. If individuals from either end of the series be mated, their offspring will be widely different from the average of the series, but will nevertheless approach that average more nearly than their parents, and no amount of selection will serve to raise or lower the limits of the series, that is, to increase the original variability. In the cases of Johannsen's beans and Jennings's *Paramoecia* and similar cases above cited however, selection does serve to sort out groups of individuals whose

characters (weight, length, etc.) center around a new mode which is higher or lower than the original. If the character



FREQUENCY-POLYGON AND CURVE

Showing variation in height of one thousand Harvard students of ages 18-25. Number of individuals shown by ordinates, and heights (in centimeters) by abscissæ. After Castle, "Genetics and Eugenics."

By permission of Harvard University Press.

of each of these groups be plotted, a series of curves is obtained, each of which represents "fluctuating" variability of the smaller group and has its own mode. If all of these

smaller curves be compounded they produce the large curve representing the larger group. In some instances the existence of several modes is seen in the original chart of a group of organisms. In other cases however mere inspection fails to reveal the compound nature of a variability curve, and only experimental analysis will tell the story.

These minor groups which when selected breed true to their own type, are the "elementary species" of DeVries, or discontinuous variations, while the "fluctuating variations" are those which fluctuate about a mode and which cannot be resolved into smaller components by selection. From this viewpoint "species" and "elementary species" may be compared in a rough way to the molecule and atom of the chemist.

The objection has been raised to DeVries' theory that his mutations are the results of hybridization, producing a new combination of characters already present, but not anything really new in itself. The wide range of mutation however among both plants and animals, wild as well as domesticated, from the large "sports" of Darwin down to those so small that they cannot be distinguished at sight from "fluctuating" variations, the fact that in some species there are periods of frequent mutation, alternating with those in which it is absent or rarer, and the possibility of inducing them artificially all speak in their favor as something new, and not due to a mere mixing and rearrangement of characters already present. Unless indeed we accept Bateson's view that most if not all variation is due to the loss of something already present, which, carried to its logical conclusion, brings us face to face with the *reductio ad absurdum* that all the possibilities of man were wrapped up in the original Amœba, or whatever it was that initiated the long line of life upon the earth.

But having analyzed the species into its component parts, having found the blocks from which the organism is built, are we any the wiser? Whence came these ultimate units, if indeed they are such, and how does Nature fashion them to her use? Are we any nearer an understanding of variation today than was Darwin?

The attack on the problem of variation has been made along two distinct lines, that of Aristotle and Nägeli, with the assumption of an "internal perfecting principle," or inherent tendency in the organism itself to vary along certain definite lines, for *unknown* reasons, and that of Eimer and his school, who believe that variation in the organism is a very definite physico-chemical response to physico-chemical

changes in its environment, either internal⁴ or external. The former method is metaphysical and unscientific; the latter, while beset by many difficulties, is the only one of promise.

What then has been done to discover the influence of environment upon variability? In a previous chapter we have briefly surveyed the influence of environment upon individual development, and have seen that this influence is often of a profound character. But is such influence lasting, does it through heredity control future as well as present generations? And this brings us face to face with one of the greatest stumbling blocks in biology; namely, the inheritance of acquired characters.

In the first place what is the meaning of the term? We owe the theory to the great French naturalist Lamarck, one of those lonely and pathetic figures who look down upon the pathway of human progress unheeded by the passing throngs. Lamarck assumed first, what is universally granted; namely, the influence of use and disuse of organs upon individual development, and second, what is generally denied; namely, the perpetuation of such influence by heredity. Thus let us suppose a group of early race horses to have increased their speed by training until they were materially faster than their parents. If now such increase in speed were handed down to their offspring, and these in turn improved by further training, and so on from generation to generation, there would evolve in time the speedy animal of today. Or if, on the other hand, a race of fishes living at one time in the open, for some reason or other, perhaps to escape the attack of enemies, took to dwelling in caves, where sight was of little advantage; there would in course of time, through lack of use of sight, develop the blind cave fishes of the present. The theory is the prettiest and simplest of the *modus operandi* of evolution which has been proposed, and could it be proven, would remove many difficulties in our path. Unfortunately however proof thus far is lacking. Skepticism toward the theory has been mainly founded on failure of mutilations of various sorts (circumcision among the Jews, cramping of feet by the Chinese, docking of horses' tails), and finally Weismann's classical experiments in amputating the tails of twenty-two generations of mice, to produce any inheritable modification whatever in the parts so mutilated. It should be noted however that while Lamarck's theory postulates use and disuse as the prime factors in causing change, some of the mutilations above cited do not involve the factors of use

⁴ Ultimately "internal" changes themselves are probably referable to external causes. I have in mind the manifold metabolic changes, which may produce variation. Regarding this we have no certain knowledge.

and disuse and consequently have no bearing whatever on the question at issue. Whoever heard, for example, of a horse with a docked tail ceasing to use the stump just as vigorously in fly time, as though possessed of the complete member? What was there in the mutilations of Weismann's mice to prevent the use of the muscles at the *base* of the tail? With the bound foot of the Chinese woman this objection would not apply, because the muscles of the foot are *intrinsic* to the foot itself; but in this case we have to consider the influence of the father as well as the mother upon the children, and the practise of foot binding in China has been limited to the female sex.

Are there then no environmental influences which are transmitted from parent to child? Is environment a negligible factor in evolution? On the contrary it is undoubtedly the most potent factor, either indirectly in the preservation of those variations (however caused) best fitted to survive, or directly in the induction of variation itself.

The seed of a flowering plant is the plant itself in miniature, containing more or less "endosperm" or nourishment for the growing seedling, until it is able to take root, unfold its leaves and obtain its own sustenance from the soil and air. If the chemical environment of the developing plant (the young ovule) be modified, what effect will this have on the adult plant? This question led MacDougal, director of the Desert Botanical Laboratory of the Carnegie Institution, to inject various solutions of zinc, calcium, iodine, etc., into the ovaries of many species of plants, with the result that the ovaries so treated produced seeds from which developed plants showing many modifications in form of leaves and flowers and markings of the latter, as well as in the form of the plant as a whole, and some, at least, of these variations have persisted through several subsequent generations.

The common potato bug has in part redeemed its shady reputation, by materially aiding us in our search for the ultimate factor of evolution, namely, the origin of variation. This beetle was originally an inhabitant of Mexico. Feeding upon the night-shade, it followed its food plant northward, and the early settlers found it established on the eastern slope of the Rocky Mountains. The spread of its food plant is attributed by Professor Tower, who has made an exhaustive study of the beetle and its habits, to the movements of the early Spanish explorers, and to the migrations of animals, especially the buffalo, whose mighty herds in early days were wont to wander north and south across the plains with the changing seasons, and in whose furry coats the burrs of the night-shade might readily have been entangled. The early

settlers brought with them plenty of English grit, Scotch whiskey and Irish potatoes; and the beetles, finding the latter more to their liking than their native food, soon showed proper appreciation of the good things set before them, and became inveterate potato feeders. After this change in the diet, it was not long before they had overrun all of the eastern United States and lower Canada.

There are many species of these beetles, distributed in different parts of the range of the genus, and most of them show considerable variation. There are two generations each season, the duration of each varying both with the species and the locality. The beetles retire for the winter underground and upon emergence in spring, seek out the potato plants, upon which the eggs are laid. From these hatch the grub-like larvae, which after a varying period cease feeding, and drop to the ground into which they burrow and there pupate, surrounding themselves with a thin shell. From this the adult beetles escape, make their way to the surface and proceed to a repetition of this performance, the second brood of beetles hibernating in the earth at the end of summer. If the larvae are taken soon after hatching and kept in experimental cages at higher or lower temperatures than normal, or in more or less humid atmospheres, or in various combinations of temperature and humidity, until development is complete, the adult beetle developing from them will be lighter or darker in shade and will show many differences from the usual color pattern, these differences in many cases closely corresponding to differences in beetles from different localities. Thus it was possible to produce in the laboratory in Chicago beetles resembling closely those occurring in nature in Arizona. The same stimulus produced different results depending upon its strength. Thus a moderate increase of temperature made the beetles darker in color, while a greater increase made them lighter, and precisely similar results were obtained by lowering the temperature, and by raising and lowering the relative humidity.

But these results were temporary, lasting for one generation only, and were not inherited. If on the other hand the beetles, shortly before egg-laying occurred, were subjected to similar conditions, variations were produced which persisted in subsequent generations. In the former case only the "soma" or body cells of the individual were affected; in the latter, the germ cells at a sensitive stage in their development—at least so Professor Tower interprets his results. Samples of some of his "creations" are shown in the accompanying figure.

Not alone by laboratory experiment is it possible to control

evolution in the potato beetle. The same experiment has been performed in Nature's laboratory by transferring beetles from the relatively cool, moist climate of Chicago to the hot arid air of Tucson, Arizona. As a result of this transfer not only are morphological (color) changes induced, but physiological ones as well. The beetles gradually acquire the power to re-



MUTATIONS IN THE POTATO BEETLE

2 represents a type derived experimentally from 1 by the use of high temperature. 5 was derived from 4 by using high temperature and relative humidity and 7 from 8 by high temperature and low humidity. From Tower, "Evolution in Chrysomelid Beetles," Carnegie Institution, Publication No. 48.

tain more water in their tissues during hibernation, and thereby to resist the effects of the dry climate. They show also certain changes in their responses to stimuli. These changes moreover are not reversible, but persist when the beetles are returned to their original home at Chicago. They

behave furthermore as definite, fixed characters in inheritance, Mendelizing when crossed with the original stock.

It is well known that the X-rays and those of radium and related substances exercise a profound influence on living tissue. In general the influence of such agents has been destructive, inducing abnormal developments of various sorts. The careless use of X-rays has been the cause in some instances of cancer, while on the other hand their use, and especially that of radium rays has been advocated as a cure for this disease. Unfortunately the results in this direction are as yet unsatisfactory.

In some instances it has been possible to produce changes in the developing organism without any apparent injury to it. One of the prettiest experiments of this sort is that of Gager, who exposed the pollen of one of the evening primroses to radium rays, and obtained a few individuals with thick, leathery leaves from ovules fertilized by this pollen, which character reappeared in their offspring. That such radiations produce profound effects upon the structure of the cell is shown by exposing growing root tips to their influence, the mitotic figures in the dividing cells being greatly distorted thereby.

The probable influence of environment upon animal form and color is very clearly shown in the extensive collections of birds and mammals made by American ornithologists and mammalogists, especially those of the U. S. Biological Survey, in which an almost endless series of gradations may be seen between the various "geographic races" of one "species"⁵ from different parts of North America. These variations are so great in some cases that specimens from extremes of the geographic range would not be recognized as members of the same species, did not a complete series of intergrades exist.

If one compares a mammal, a field mouse let us say, from Florida or tropical Mexico with its nearest relative from Labrador or Alaska, he will find the legs, ears and tail of the former a trifle longer, and the fur a little lighter than the same parts of its northern cousin. Is it mere accident that the northern mouse is more warmly clad, and has appendages which are shorter, and consequently less liable to freeze, than the southern one? Or is it a question of survival, has Nature selected those individuals best adapted to the regions where they live? Or yet again, is this a case of the influence of environment, and if so, has the latter di-

⁵ According to some writers these "geographic races" are accorded the status of "species." The question of terminology does not however influence the facts in the case.

rectly affected the germ cells, or has such influence been transmitted to them indirectly, by affecting first the body cells of the parent, which effect has been secondarily transmitted to its germ cells? If the latter is true, it would go far to establish Lamarck's theory of the inheritance of acquired characters. In an attempt to solve this problem, Sumner has reared several generations of white mice under different conditions of temperature and relative humidity. The mice were kept in unheated and heated rooms respectively, in the former of which the relative humidity was much higher than in the latter, although in neither were the conditions at all constant. As a result the mice in the cold room developed a greater amount of hair and shorter tails, feet and ears. These differences however diminished as the mice grew older. Unfortunately his equipment did not enable him to control his factors properly, so that his comparisons were made between the general conditions of greater and less heat and moisture respectively, and not between definite degrees of these factors. However his results do show a rather definite influence of temperature and humidity, not alone upon the parents, but also upon their offspring of the first generation. These results, so far as they go, show then that environment may directly affect not only the organism itself, but also its offspring.

When we come to the question however of how these results were obtained, we are very much at sea. In the case of Tower's experiments described above there can be little doubt that the influence of the external factors upon the germ cells was direct, because inheritable variations were obtained only when the experimental factors were operative at a certain definite time in the development of the germ cells. Here too the latter, in the body of an animal whose temperature is not constant, but varies with that of its environment, are readily subject to environmental influence, at least so far as temperature is concerned. In the case of humidity it is more difficult to see how the germ cells could be directly influenced. In mice however whose body temperature and moisture is constant under normal conditions, regardless of external factors, it is impossible to postulate a direct action of such environmental factors upon the germ cells, and the only possible interpretation to be placed on Sumner's results, assuming their accuracy, is that of an indirect influence of external factors upon the germ cells, through changes primarily induced in the body cells or soma, and secondarily transmitted from them to the germ cells; i.e., the inheritance of acquired characters.

Unfortunately Sumner's results have not been, so far as

I know, substantiated by any other investigator, and his own, more recent work in California has strikingly failed to support his previous experiments. In his later work Sumner has been studying the relation between climate and color of several races of California deer mice (*Peromyscus*). The climate of California presents all possible gradations, from the arctic conditions of the Sierra summits to the torrid heat of the southern valleys, and from the humid air of the northern coast to the parched atmosphere of the interior deserts. Widely distributed over the state the ubiquitous deer mouse



THE DEER MOUSE, *PEROMYSCUS*

Photo by E. R. Warren.

is found with three distinct varieties of one species, one of which occupies the cold humid coast region from San Francisco northward, another the interior, including both mountains and valleys, and the southern coast, while a third lives in the hot, arid deserts of the southeastern part. Possibly a more ideal region for studies of environmental influence on variation could not be found. Sumner has reared several generations of mice taken from the humid northern coast, and the desert to the southern coast at La Jolla, and to Berkeley on San Francisco Bay, but thus far without obtaining any definite results. The imported mice remain true to their ancestry.

Far back in the dim shadows of the past, primitive man is represented as asking his Creator, "Am I my brother's keeper?" And that question has come down to us through all the ages, with ever-growing insistency. What measure of responsibility do we bear for the well-being, not only of our brothers of the present, but our children of the future? Does a man's conduct influence for weal or woe the lives of his children? Alcoholism is a well recognized inherited trait. But what is its origin? Can a man through indulgence in the "cup that cheers" affect the inheritance of his children? While abundant data are available from human inheritance to show its inheritability, evidence regarding its origin cannot be readily obtained here. And so the experimenter has turned to the long-suffering guinea pig, the rat and the chicken for an answer to his question. And here only indirect evidence at best can be obtained. We cannot induce an alcoholic tendency or fondness in a lower animal, or at least it has not yet been done; but we can determine whether subjecting the parent to alcohol will in any way influence the offspring, and whether such effects, if any, will persist in future generations.

Trial of several methods of subjecting animals to alcohol has shown that the best method is to allow them to breathe the fumes for stated periods daily, the length of the period being determined by the ease with which the animal is intoxicated by the fumes. The method is objectionable because of the tendency of the animals to become blind under the influence of the fumes. This does not however interfere with their breeding, nor does it reappear in the offspring. Using this method on guinea pigs Stockard has found that of one hundred and three matings between parents, either one or both of which had been treated with alcohol, forty-three were either sterile or resulted in abortions; in fourteen matings the young were stillborn, while in the forty-six matings producing a total of eighty-nine young, thirty-seven of these died soon after birth and only fifty-two survived, many of which were undersized and nervous.

MacDowell has carried out a long series of experiments to test the effects of treating rats with alcohol upon the ability of their young to learn a path through an intricate passage or "maze," which indicate that the grandchildren of young so treated learn less readily than do those of normal rats. MacDowell has also obtained a very definite effect upon the rats so treated, their weight and fecundity being materially reduced. Pearl, in a similar series of experiments on fowl, found that while the proportion of fertile eggs laid by alcoholized parents was much lower than in those from

normal parents, those which were fertile were more resistant (fewer died before hatching) and the chicks hatched were heavier than those of normal chickens. Pearl has apparently published no results dealing with the effects of alcoholism on generations later than the first, but Stockard's experiments seem to show that such effects are transmitted to the grandchildren.

In the light of these contradictory results no final word can be said regarding the influence of alcohol on animals and the transmission of such influence to subsequent generations. In neither the experiments of Stockard nor of Pearl did the treated animals themselves show any conspicuous effect (apart from blindness in the guinea pigs, which was the direct result of the action of the alcohol fumes upon the eye) although the alcoholic chickens increased somewhat in flesh and became rather lazy, a result easily paralleled in some cases in man.

Recognizing then the occurrence of variations produced by physico-chemical factors either internal or external to the organism itself, and granting that such variations may in some cases be preserved, but probably neither increased nor diminished by selection; are there other factors which may influence evolution?

In 1868 Moritz Wagner suggested the influence of geographic isolation as a factor in the evolution of plants and animals, and this theory has more recently been advocated by David Starr Jordan in this country.

One of the objections to the theory of natural selection is the swamping effect of intercrossing between nascent species. How this "swamping" is effected if new varieties are discontinuous or mutating, breed true and do not blend when intercrossed, is difficult to understand. It is possible however that the dominant types being more numerous have caused the recessives to be overlooked, and that consequently the "swamping effect of crossing" is more apparent than real. If however such objection is valid, the danger to the new species could be removed were a barrier to such intercrossing to arise between nascent types, thereby preventing them from interbreeding. That such isolation does play an important rôle in evolution, there is good reason to believe.

Isolation may be of several kinds: psychical, physiological, structural, habitudinal and geographical. It is well known that many species of nearly related animals will refuse to interbreed. In other cases in which different species of animals do interbreed the offspring are ordinarily infertile, perhaps the best known instance being the mule, which is a hybrid of the jackass and the mare. Mulatto women,

while fertile, are said to have frequent miscarriages, and after a few generations to be generally barren. In more extreme cases, while fertilization is possible and development may proceed for a time, the offspring of the cross do not attain maturity. This is especially true of crosses between widely divergent forms such as the salamander and the frog, or the sea urchin and the starfish.

In some instances isolation is effected by a difference in the time of mating of different individuals. There are many species of butterflies which have different color phases, to which reference has already been made. These color phases are apparently due to the time of year at which the eggs are hatched, whether in spring, summer or autumn. It is probable that those butterflies which hatch at the different seasons mate together, thus producing isolation of the different color phases of the same species, due to the different hatching seasons of the eggs. Inhabiting the Kermadec Islands northeast of New Zealand are two varieties of a species of shore bird, which flock together but breed at different times, thus producing isolation between them.

In other cases structural differences, notably of the external sexual organs, such as occur in various species of insects and other arthropods, effectually serve to prevent interbreeding; while yet again structural differences in the germ cells themselves interfere with cross fertilization.

Habitudinal isolation may be effected by the preference of different groups of animals for different modes of life (differences in food or habitat). Inhabiting the southern hemisphere are several species of albatrosses, which mingle with one another throughout most of their range, but breed in separate localities. Professor Kellogg, whose name is familiar to us all for his services to Belgium, some years ago made a study of the bird lice, a group of wingless, biting insects living on birds and mammals, similar in habit, though differing in structure from the "ugly, creepin' blastit wonner, detested, shunned by saunt an' sinner," but immortalized by Burns. In this study he found that while the similarity of the environment in which these lice live tends to keep the different species unchanged, nevertheless the isolation produced between groups of individuals living, it may be for years on the body of the same bird, tends to fix the minor variations which occur in all living things, and thus produce slight but noticeably distinct variations within the species.

The student of geographical distribution of plants and animals recognizes as axiomatic the fact that the more widely separated are any two regions of the earth's surface, the more

divergent will be their faunas and floras. By "separation" in this sense is meant separation in time and environment rather than space. Thus the fauna of Australia and New Zealand shows a vastly greater difference from that of the Asiatic mainland, although separated therefrom by less than 2,000 miles, than does that of Japan from England, which are about 8,000 miles distant from each other. By some biologists these differences are referred to the effect of isolation, by others to the direct influence of environment (temperature, moisture, etc.), natural selection in either case exercising the veto power or final control over the other factors. Probably all three factors are so closely inter-related in determining the final result in most cases that an exact analysis of their relative rôles is impossible. The inhabitants of central Africa, separated from those of northern Africa by less than 2,000 miles, differ more widely from each other, than do those of North America and Siberia, separated by several times that distance. But between the former intervenes the wastes of the Sahara, impassable to most forms of life, while the latter have an almost continuous land area between them, broken only by the narrow Behring Strait, which freezes in winter. Prior to the Miocene epoch a few million years ago, which is comparatively recent, geologically speaking, the Atlantic and Pacific Oceans were connected, where now extends the Isthmus of Panama. The elevation of the isthmus has thus separated an originally single fauna into two, with the result that many of the species on either side of the isthmus are represented by nearly related ones on the opposite side, both doubtless derived from one ancestral form.

In the instances already cited it is impossible to distinguish between the possible effects of environment, selection and isolation; in fact, it is very probable that all of them have worked together in producing the final result. But in the case of the land snails of the Hawaiian Islands, the two former factors are seemingly ruled out, and isolation appears to have been the only factor involved. The Hawaiian Islands are a group of volcanic origin, the chief of which, Oahu, consists of a long mountain ridge, rising to an elevation of 4,000 feet above the sea, from which extend numerous lateral ridges, with deep intervening valleys. Inhabiting these valleys are 800 or 1,000 different varieties of land snails (*Achatinellidæ*), over 200 of which the conchologists recognize as "good species." These snails feed upon the vegetation in the valleys and seldom cross the high rocky ridges of the intervening slopes. Each valley therefore has its own community of snails, which is effectively isolated from neighboring communities, but a few miles distant. As a result of such iso-

lation there have developed in each valley varieties peculiar to it. In some cases a species is restricted to a single valley, while in others it may extend over two or three adjacent ones. The most nearly related forms are found in adjacent valleys, and the most divergent in those widely separated. Gulick, who has made a special study of these snails, says, "I had found not simply a large section of the world, within which peculiar species had originated, but ascending a certain mountain ridge a few miles from Honolulu, and looking down, I could say, 'That valley to the right, a couple of miles in length and half a mile in width, is the birthplace of the *Achatinella producta* and *Achatinella adusta*; and within the groves of this valley upon which we look on our left were created *Achatinella stewartii* and *Achatinella johnsonii*; while behind us a mile to the northeast, in the jungle that clings to the almost precipitous cliffs on the other side of the backbone of the island, is the secret home of the very rare and beautiful *Achatinella versipellis*.'" ⁶

Crampton, who has made an extensive study of the distribution, variation and evolution of the land snails of the genus *Partula*, inhabiting Tahiti, one of the Society Islands of the South Pacific, forms closely related to the *Achatinellidæ* of Hawaii, has reached conclusions similar to those of Gulick. He finds that "with only one exception each group of islands has its own characteristic species which occur nowhere else," while with few exceptions each island in the different groups "possesses distinct species not found in the others," and the species "may vary from valley to valley of an island; one form sometimes extends over a wide range, while another may be restricted to a few valleys or even to one." ⁷

In many of the habitats of the different species of snails of Oahu and Tahiti, the environment is seemingly identical. In two adjacent valleys, but two or three miles apart, different species of snails may be found, feeding on the same trees at similar altitudes and experiencing the same degrees of temperature, humidity and barometric pressure. In some cases contiguous valleys present greater differences in vegetation than those more widely separated, and yet the diversity of the snails in the former case is less than in the latter. Divergence of environment is therefore obviously not the cause of the differences involved. Nor is there any apparent influence of selection. When two environments differ widely,

⁶ Gulick, "Evolution, Racial and Habitudinal," Carnegie Institution, Publication 25, pp. 1-2.

⁷ Crampton, "Variation, Distribution and Evolution of the Genus *Partula*," Carnegie Institution, Publication 228, p. 11.

selection may step in to eliminate a species which is not adapted to one or the other of them. But as we have just seen there is no correlation between differences in the snails themselves and amount of difference in their surroundings. Nor do the possible enemies of the snails differ in their distribution in the different regions.

Isolation however cannot of itself have caused these differences which must have arisen by spontaneous variation of the snails themselves, due to factors as yet unknown; isolation playing merely a preservative rôle in maintaining the variations thus originated, which tend to increase by "orthogenesis," for reasons equally obscure.

For several years past Dr. Paul Baartsch of the Smithsonian Institution has been carrying on an interesting and significant experiment, when taken in conjunction with the studies of Gulick and Crampton on the snails of the Pacific Islands. Baartsch has employed a genus (*Cerion*) of land snails found in Florida, the Bahamas, Porto Rico and neighboring islands. Several colonies of these have been transplanted to the Florida Keys, and while the plantings have not in every case been successful, many have thrived and after some years in their new home, the snails in some instances have shown marked differences in size from the original type. His results are as yet too incomplete to permit of generalization however.

Out of all the haze of evolutionary theory do any facts loom large against the background of the past? We may I think safely say that evolution itself is such a fact; that organisms tend to vary for reasons in the main as yet obscure, but undoubtedly due in the last analysis to the influence of environment, either internal or external to the organism itself; while natural selection and isolation play an important, but secondary rôle, by preserving those variations which are fitted to survive.

CHAPTER X

Experimental biology continued. Mendelism and the multiple factor hypothesis. Human inheritance and eugenics.

We have considered in a previous chapter the physical basis of inheritance and have seen that the manifold characters of organisms are probably determined by certain entities in the cell, which are shuffled about at the time of maturation like the cards in a pack or dice in a box, and recombined in fertilization so as to produce entirely new combinations of characters in the offspring. In the present chapter we shall consider the applications of these facts to inheritance in organisms in general and man in particular, with especial reference to eugenics or the improvement of the human race.

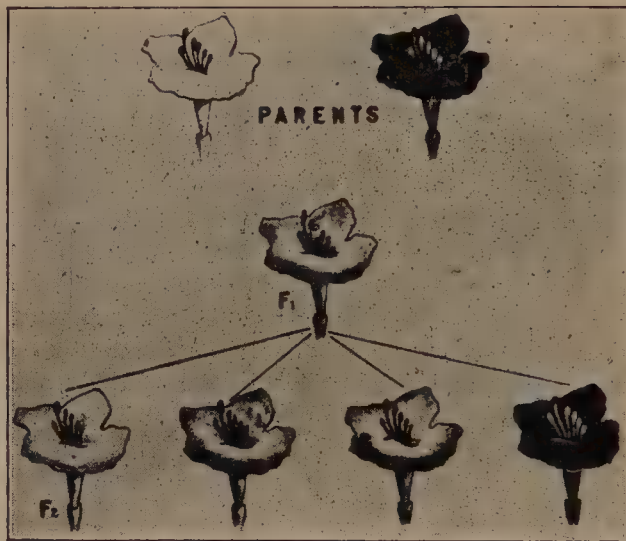
While variation is the foundation of evolution, inheritance may be likened to the keystone of its arch, without which permanence would be impossible. The truth of inheritance has been recognized throughout the ages. Aristotle and other early writers discuss it. "Plutarch mentions a Greek woman who gave birth to a negro child, and was brought to trial for adultery, but it transpired that she was descended in the fourth degree from an Ethiopian."¹

Many types of inheritance have been recognized in the past (reversion, atavism, telegony, particulate, blending, etc.), but modern research points strongly to a single method, modified indeed by many factors, but nevertheless uniform in its underlying principle. So far at least as higher types of life are concerned. When we come to the beginnings of life, to the unicellular forms and the simpler metaphytes and Metazoa, our knowledge is too limited to admit of anything approaching generalization. In the unicellular forms the mechanism of inheritance itself is evolving, and the type of inheritance must therefore of necessity be indeterminate.

The essential feature of Mendelian inheritance is not the dominance of one trait over another, but rather the persistence of identical traits from generation to generation (un-

¹ Ribot, "Heredity," p. 167. D. Appleton and Company. While Plutarch's information was probably faulty, viewed in the light of modern research, his statement nevertheless shows the belief of his day in the controlling influence of heredity in human life.

modified by other traits) in the make-up of the organism. The basis of this persistence we have already seen to be the chromosome. In those cases in which one character dominates another (tallness vs. dwarfness in peas, color vs. albinism in animals, etc.), we have the phenomenon known as latency, in which the determiner of a character may be passed along for several generations, without the character itself coming to expression. In such cases the character is definite and the individual is distinct in respect to its possession. There is no uncertainty for example, as to whether



INHERITANCE OF COLOR IN THE FOUR O'CLOCK

F₁, F₂, first and second generations. From Morgan, Sturtevant, Muller and Bridges, "Mechanism of Mendelian Inheritance."

By permission of J. B. Lippincott Company.

a guinea pig is spotted or uniform in color, or a man's hair is curly or straight. There are cases however in which the organism is neither "fish, flesh, nor good red herring," or speaking scientifically dominance is imperfect or incomplete. The four o'clock (*Mirabilis jalapa*) has a white- and a red-flowered race, which when crossed produce plants with pink flowers. When these pink-flowered plants however are bred *inter se* they produce 1 red to 2 pink to 1 white offspring, the first and last classes of which breed true, while the middle class when inbred continues to "throw" red, white and pink plants in the above ratio. A crude chemical analogy to these phenomena may be made in the following way: At

ordinary temperatures chromic sulphate forms a violet-colored solution in water, but at lower temperatures the salt crystallizes out leaving the water colorless as before. A concentrated solution, deep violet in color, may be taken to represent the color of the red-flowered four o'clock, while water may represent the color of the white-flowered variety. By mixing the concentrated solution and water in equal quantities, a solution of light violet color is obtained, which may represent the pink-flowered hybrids of the first generation. If this dilute solution be now divided into four equal parts,



INHERITANCE IN ANDALUSIAN FOWL

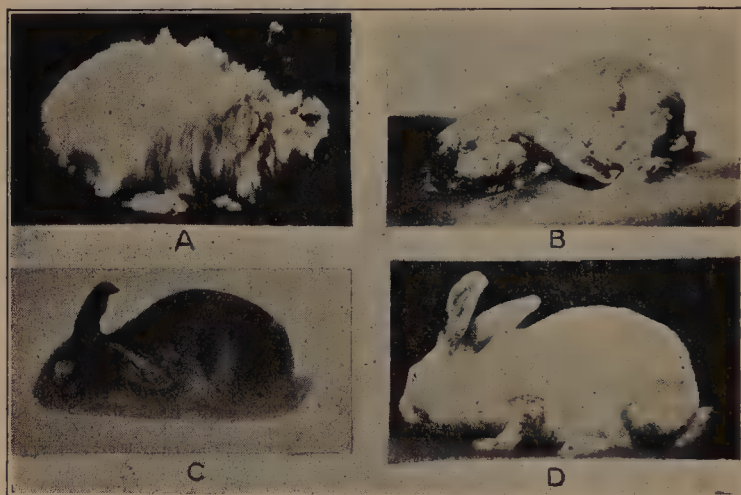
P₁, parents; F₁ and F₂, the first and second generation offspring of the cross. From Morgan, "The Physical Basis of Heredity."

By permission of J. B. Lippincott Company.

to one of which a sufficient volume of salt be added to restore the original color, while two are left unchanged and the fourth is cooled, thereby separating the salt from the water and leaving the latter colorless, a superficial analogy to the phenomena of color inheritance in the four o'clock is obtained. I say "superficial" or "crude" analogy, because the physical process outlined above is far too simple to represent the complicated bio-chemical processes involved in that of inheritance.

One of the best known cases of imperfect dominance is that shown by Andalusian fowls, although as we shall see this case is not strictly comparable to the preceding. The "blue" Andalusian is a chicken in which black is mixed with white

in very small flecks. If two blue Andalusians are crossed they produce one black, two blue, and one white splashed with black; while when the first and last of these offspring are interbred, only "blue" fowls result—a Mendelian proceeding, which is strictly "according to Hoyle." Here we have two factors, black and white, which instead of blending in the cross enter into it unmodified, but distributed in such a way as to produce a result different from that of either parent. Furthermore, the "recessives" here carry a little of the "dominant" factor in the splashes of black on a white background.



INHERITANCE OF EAR LENGTH IN RABBITS

Figs. A and B, parents; C and D, offspring of the first and second generations, respectively, with ear lengths intermediate between those of the parents. From Castle, "Genetics and Eugenics."

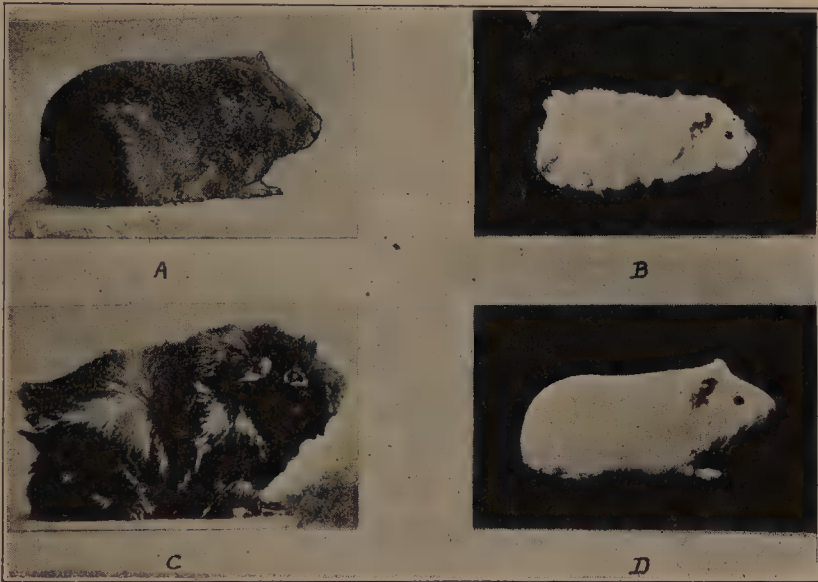
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A closely similar case is that of red and white cattle, which, when interbred, produce "roan" offspring, these latter in their turn "throwing" red, roan and white in the proportion of 1:2:1.

In some cases of supposedly complete dominance careful measurements show that the dominant factor is slightly modified by the recessive. Thus when wild fruit flies are crossed with those having small wings, the long wings of the former dominate the short wings of the latter; but not completely, for the wings of the hybrid average slightly less than those of the wild parent. And this gives rise to the question whether dominance is ever perfect, even in those cases in

which it appears to be so. The fundamental fact in Mendelian inheritance then is segregation, not dominance.

In the cases just cited segregation is perfectly evident in the second generation, but there are cases in which it is not. There is a breed of domestic rabbit known as the "lop-eared" rabbit in which the ears are very long and pendant. When such a rabbit is paired with the ordinary kind, the ears of the hybrid are intermediate in length, and this condition persists in succeeding generations. Is this not a true



INHERITANCE IN GUINEA PIGS

Figs. A and B, the parents; C, the first generation, the second generation containing animals of all four types, A, B, C and D. From Castle, "Genetics and Eugenics."

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"blend" between different degrees of ear length? The mulatto is another example of an apparent blending of characters in inheritance. Is a different interpretation possible?

There are certain varieties of corn with yellow kernels, which when crossed with white corn give yellow offspring. These latter, when mated with each other, give, instead of the usual Mendelian ratio of 3:1, fifteen yellows to one white. This is exactly what we should expect if there were two characters involved in producing the color of the yellow variety, for when two pairs of factors are involved in a cross—i.e., tall, red peas x dwarf whites; long-winged, gray fruit flies x black, dwarf-winged; black, rough ("rosette") haired guinea

	B	b
B	BB	Bb
b	Bb	bb

	BR	Br	bR	br
BR	BR BR	Br BR	bR BR	br BR
Br	BR Br	Br Br	bR Br	br Br
bR	BR bR	Br bR	bR bR	br bR
br	BR br	Br br	bR br	br br

	BRS	BRs	BrS	Brs	bRS	bRs	brS	brs
BRS	BRS BRS	BRs BRs	BrS BRs	Brs BRs	bRS BRS	bRs BRS	brS BRS	brs BRS
BRs	BRS BRs	BRs BRs	BrS BRs	Brs BRs	bRS BRs	bRs BRs	brS BRs	brs BRs
BrS	BRS BrS	BRs BrS	BrS BrS	Brs BrS	bRS BrS	bRs BrS	brS BrS	brs BrS
Brs	BRS Brs	BRs Brs	BrS Brs	Brs Brs	bRS Brs	bRs Brs	brS Brs	brs Brs
bRS	BRS bRS	BRs bRS	BrS bRS	Brs bRS	bRS bRS	bRs bRS	brS bRS	brs bRS
bRs	BRS bRs	BRs bRs	BrS bRs	Brs bRs	bRS bRs	bRs bRs	brS bRs	brs bRs
brS	BRS brS	BRs brS	BrS brS	Brs brS	bRS brS	bRs brS	brS brS	brs brS
brs	BRS brs	BRs brs	BrS brs	Brs brs	bRS brs	bRs brs	brS brs	brs brs

DIAGRAMS ILLUSTRATING INHERITANCE IN GUINEA PIGS

Of one, two and three pairs of characters respectively. B=black, b = white, R = rough coat, r = smooth coat, S = short hair, and s = long hair. The second generation results are, respectively, 3 black, 1 white; 9 black-rough, 3 black-smooth, 3 white-rough, 1 white-smooth; and 27 black-rough-short, 9 black-rough-long, 9 black-smooth-short, 9 white-rough-short, 3 black-smooth-long, 3 white-smooth-short, 3 white-rough-long, and 1 white-smooth-long, which result from the summation of the combinations in the above diagrams.

pigs x albino, smooth-haired; dark, curly x light, straight hair in man, etc., there is only one out of sixteen offspring in the second generation in which *both* of the recessive factors come to expression. Thus in the case of black rough x white smooth hair in guinea pigs, only one in sixteen second generation offspring will be white with smooth hair. This result follows as a mathematical necessity of the chance combination of two pairs of characters, just as the 3:1 ratio results from the combination of one pair. Similarly if three pairs of characters are involved in a cross, i.e., black, rough, short and white, smooth, long hair in guinea pigs, there will be only one out of sixty-four offspring in the second generation, which will show all three recessive characters. And if four pairs are involved, only 1 in 256, etc. A graphical representation of these results is given in the accompanying diagrams, which make sufficiently clear the chance combination of characters in Mendelian inheritance.

That two factors may be involved in the production of an apparently simple character is conclusively shown in the case of the sweet peas described by the English naturalist, Bateson. Bateson found that when two white peas were crossed they produced colored offspring, which he interpreted as due to the presence of two factors, one in each of the white parents, which, uniting in the cross, produced a colored pea. The results obtained by inbreeding these colored offspring, details of which need not figure here, showed clearly that two pairs of Mendelian factors were concerned. In the case of the corn cited above a single factor for yellow produces the same apparent result in the first generation, as do two factors, but in a variety of oats described by the Swedish breeder Nilsson-Ehle, a different result is obtained. In this case a variety of oats characterized by dark brown glumes or husks, when crossed with a white-glumed variety produced in the second generation nine plants with dark brown, six with light brown, and one with white glumes. This result may be explained as due to the presence of two factors for brown in the dark-glumed plants, one only in those with light brown glumes and none in those with white glumes. It is obtained in the same way as in the second diagram, two factors for brown being substituted for black, rough.

The theory that two or more factors may in some cases combine to produce an apparently simple result is known as the "multiple factor" hypothesis. In the case of lop-ear in rabbits and color in man, the results are readily explicable by means of this hypothesis on the assumption (1) that several factors are involved in the production of the character in question, (2) that in order to produce the maximum result

the full number must be present, and (3) as a corollary to (2) if less than the full number are present the result will be more or less intermediate or "blending" between the maximum of the character and its total absence. Thus, let us assume with Davenport that the African negro contains four factors for blackness, while the white man has none. Two factors produce a "mulatto," one a "quadroon," and three a "sambo," while the "octoroon" and the "near-white" resemble the pure white, so far at least as skin color is concerned. The offspring of a cross between a full black and a white will be a mulatto containing two factors for black. If the latter marry a white the offspring will be of three classes, 1 mulatto, 2 quadroons and 1 "near-white." A cross between two mulattoes will result in 1 black, 4 sambos, 6 mulattoes, 4 quadroons and 1 "near-white," a result readily derived from the second diagram on page 262 if for the dominant factors we substitute the factors for negro color BB. Thus the chance of either original color (black or white) appearing in the second generation is only 1:16, while there are 14 chances of an intermediate or "blending" color appearing. If more than four factors are involved, the chance of either of the original characters reappearing in the second generation of a cross will be correspondingly lessened. Thus if six factors (3 pairs) are involved the chance will be 1:64, with 8 factors (4 pairs) 1:256, with 10 factors (5 pairs) 1:1024 and with 12 factors (6 pairs) only 1:4096. Such an hypothesis readily explains on a Mendelian basis the case of the lop-eared rabbit if we assume the necessity of several factors in the production of a superficially simple, but fundamentally complex result.

An interesting corollary of Davenport's main thesis, founded on a study of more than a hundred negro-white families in Jamaica, Bermuda and Louisiana, is the overthrow, or at least serious weakening of the popular belief that a marriage of two "near-whites" may result in children of negro color. His results indicate that the offspring of a cross between persons of negro ancestry, can in no event have more than the sum of the factors for black of the two parents; so that the children of two "near-white" parents can never produce other than white children, while a near-white and a quadroon can at most have only quadroon children.

The basis of Mendelian inheritance is, as we have seen, the chance combination in calculable proportions of definite characters, which are segregable from one another, and do not form permanent "blends." How well do the calculated or

"expected" results agree with those actually obtained in breeding experiments? Obviously the larger the number of individuals the greater the probability of agreement between expectation and realization, and when the former is small, say 1:64 or 256, a very large number of tests may be necessary before it can be realized. While the correspondence between expectation and realization is seldom exact, the agreement is nevertheless generally close enough to furnish a substantial basis for the theory. A few random examples may be cited. In the common weed, the shepherd's purse (*Bursa bursa-pastoris*) there is a variety with round and another with triangular fruits. The latter dominates the former and is determined by two factors. Therefore the expectation for round vs. triangular fruits is 1 in 16. In a total of 2907 second generation hybrids Shull found 2782 with triangular and 125 with round fruits, a ratio of 23.3 to 1, as compared with an expectation of 2725 of the former and 182 of the latter, a ratio of 16 to 1. In crosses between quadroons and whites Davenport found out of 99 children there were 42 "near-whites," 56 quadroons and 1 mulatto, whereas the expectation was an equal number of "near-whites" and quadroons and no mulattoes. In another series of matings between quadroons he found out of a total of 134 children, 24 "near-whites," 87 quadroons and 23 mulattoes, the expectation being 3.5, 67 and 33.5 respectively.

Any rabbit breeder knows what a mixture of colors and markings he may expect in his product. Professor Castle, who has recently analyzed the color varieties of rabbits, classifies them as follows: gray, black, yellow (with white belly and tail), sooty (a variety of yellow with the belly and tail colored like the rest of the body), and white. The first four of these may in turn be modified by intensity of pigment (dark or light), by its uniformity, or lack of uniformity (spotting), and the white may be either wholly so or cream colored with black nose, ears, feet and tail (the so-called "Himalayan" of the fanciers). This makes a total of eighteen varieties in all, which when interbred can theoretically produce 243 different varieties, different, that is, from the viewpoint of their hereditary structure, not in their external appearance, for things "are (very often) not what they seem" in genetics. Many of these varieties have been obtained, others still remain to be "created." There are thirty-two possibilities in gray rabbits, many of which are already known. As a comparison of the results realized with those expected when one variety of these grays is crossed with itself, the following table from Professor Castle's paper is of interest:

<i>Color</i>	<i>Observed</i>	<i>Expected</i>
Gray	24	27
Black	8	9
Yellow	16	9
Sooty	2	9
Blue-gray	8	3
Blue	2	3
Cream	3	3
Pale sooty	2	1

Another cross between two grays of a different sort gave the following results as compared with those to be expected:

<i>Color</i>	<i>Observed</i>	<i>Expected</i>
Gray	20	27
Black	8	9
Yellow	12	9
Sooty	1	3
Blue-gray	7	9
Blue	4	3
Cream	(?)	3
Pale sooty	1	1
White	8	21

"The category yellow is probably too large because of a failure on our part to discriminate between yellow and cream, a difference which at first we failed to record. It is possible also that albino young were not enumerated in all the records which we have combined, and so albinos are apparently deficient in number."²

What is the new science of genetics doing for the world in a practical way? It is scarcely necessary to suggest that a knowledge of inheritance is fundamental to the practice of breeding animals and plants. But the new genetics is scarce two decades old, while during the preceding centuries man has produced the wonderful diversity in domesticated varieties which we know today. Has all this earlier improvement been due to chance alone? Is the scientific breeder a product of the last twenty years? Hardly, for we are using today the same principle of selection which has been the magic wand of the breeder in the past. But to this principle has been added more accurate knowledge of kinds of variation and the laws of their inheritance, so that today the breeder can work more surely and swiftly than his predecessor in the past.

² Castle, "Inheritance in Rabbits," Carnegie Institution, Publication No. 114, p. 59.

A few examples of what breeders have accomplished may be of interest. Professor Castle has shown that there is in guinea pigs a factor which restricts black and brown pigment to the eyes, while yellow pigment is unaffected by it. When a brown pig is crossed with a black-eyed yellow one containing this factor, some of the offspring receive it in combination with the factor for brown and are consequently brown-eyed yellow—a new “creation” unknown before Castle’s experiments were made. While brown-eyed yellow



A HERD OF HORNLESS CATTLE

Hornlessness may be bred in cattle by proper attention to Mendelian laws.

Courtesy of the U. S. Bureau of Animal Industry.

guinea pigs may not mean any more to the fancier in dollars and cents than do black-eyed yellow ones, nevertheless the experiment demonstrates the possibility of scientific breeding in the production of varieties which do have economic value.

The presence of horns on a vicious bull, or a refractory cow, has always constituted a serious menace to the owner’s peace of mind, and often such animals have to be dehorned. But the breeder has a better means for dehorning his stock, for lack of horns in cattle is dominant to the horned condition, and by crossing horned cattle with hornless ones of other

breeds it is possible to produce hornless cattle in breeds which are usually horned.

The "upland" cotton of the South has a short fiber which is worth much less than the long fiber of the "sea island" variety. The former however is a much better bearer than the latter, and has a pod which opens widely, rendering the cotton more easy to pick, while the latter is more easily ginned, the fibres not adhering so tightly to the seeds. By crossing "upland" and "sea island" plants, the U. S. Department of Agriculture has produced a prolific race of "sea island" cotton, with wide-opening bolls, thereby adding hundreds of thousands, if not millions of dollars annually to the value of the cotton crop in the United States.

We are all familiar with the frequent alarms that come from Florida to the effect that the orange crop is a failure due to some recent freeze. And we can never be quite sure whether the freeze is genuine, or faked for the purpose of making us pay a premium for Florida's delicious fruit. Oft-times however the danger to the orange grower is very real, and many a sleepless night he spends tending the bonfires in his groves to save his crop from ruin. And so the plant breeder has come to his rescue and by crossing the hardy, frost-resistant orange of Japan with the Florida orange, has produced a fruit known as the citrange with many of the good qualities of the orange and yet capable of resisting a temperature as low as 8°F.

These instances might be multiplied many-fold, but they must suffice as a suggestion merely of the possibilities open to the scientific breeder of the future.

But in no direction has Mendelism better served than in the development of the new science of eugenics, concerning which we hear so much today, both of fact and fancy. The germ of the eugenic idea is contained in the witticism of Oliver Wendell Holmes, who, when asked for advice on how to reach a good old age, replied that the best way was to select long-lived grandparents.

It is indeed true that, as Kimball says in his fascinating essays on the "Romance of Evolution": "The scientific way of selecting a wife and falling in love, going first to a phrenologist and getting a chart of her skull with all its bumps, combativeness, destructiveness and the like marked upon it, then to the physiologist to find out whether her temperament is bilious or phlegmatic, then to the family physician to make sure she is free from scrofula and consumption and then to the woman herself to exchange, not vows but charts and certificates, is not certainly on the face of it quite so romantic as where Arthur and Amelia fall in love with each other at

first sight, and after the requisite number of haunted castles, diabolic rivals and cruel partings rush exactly at the end of the second volume ecstatic into each other's arms. But this destructive and prosaic side of science is only its beginning, only the clearing away of the old rubbish to lay the foundation of a nobler and fairer structure. Its first object is indeed truth, truth whatever the ugliness and humility of its outlines may be. But truth and beauty in their final result are always sure to blend together and always nourish and require in those who follow them to the end something at least of their own grand and heroic qualities. Truth here, the same as elsewhere, is found to be stranger than fiction, the world effect, however prosaic its surface may be, to have roots which go down to infinite depths of mystery. And scientific discovery dealing with these truths and facts has come already to a revelation, lit up the world too with a light, that for romance and wonder surpasses all that was ever seen or dreamed of in the grandest days of old."³

We speak of eugenics as new and yet as a matter of fact the eugenic idea dates back to the time of Plato, who advocated in his republic the building of a better state by the elimination of the unfit, and who urged the appointment of a state official for this purpose. Since Plato's day many visionary schemes have been suggested for the improvement of the human race, but the modern movement is due to the great English geneticist, Sir Francis Galton, who, in his "Hereditary Genius" published in 1869, pointed out the desirability of improving the human race. His suggestions fell upon stony ground, but with the confidence bred of conviction he returned undaunted to the struggle, and the outcome of his efforts was the establishment of the Eugenics Laboratory of the University of London in 1905, which under the direction of Karl Pearson is collecting data on human inheritance, and publishing them in its "Treasury of Human Inheritance."

In America the movement for race betterment has been largely in the hands of the Eugenics Section of the American Breeders' Association and the Eugenics Laboratory, a brief account of the work of which latter institution has been given in the chapter on American Biological Institutions.

In the following pages we shall consider briefly a few examples of human inheritance, both mental and physical, and the burden of the unfit which society has to bear, together with an outline of what the practical eugenicist pro-

³ Kimball, "The Romance of Evolution," pp. 3-4. American Unitarian Association.

poses for the amelioration of social ills and the building of a better human race. The cases of the Jukes and the Kāl-likaks on the one hand, and the family of Jonathan Edwards on the other, are classics and have been cited so widely as to require no repetition here. An equally instructive case is that cited by Goddard from his studies of the inmates of the New Jersey Training School for the Feeble-minded. The history of this case is described by Goddard in the following words: "Here we have a feeble-minded woman who has had three husbands (including one 'who was not her husband'), and the result has been nothing but feeble-minded children. The story may be told as follows:

"This woman was a handsome girl, apparently having inherited some refinement from her mother, although her father was a feeble-minded, alcoholic brute. Somewhere about the age of seventeen or eighteen she went out to do housework in a family in one of the towns of this State (New Jersey). She soon became the mother of an illegitimate child. It was born in an almshouse to which she fled after she had been discharged from the home where she had been at work. After this, charitably disposed people tried to do what they could for her, giving her a home for herself and her child in return for the work which she could do. However she soon appeared in the same condition. An effort was then made to discover the father of this second child, and when he was found to be a drunken, feeble-minded epileptic living in the neighborhood, in order to save the legitimacy of the child, her friends (sic) saw to it that a marriage ceremony took place. Later another feeble-minded child was born to them. Then the whole family secured a home with an unmarried farmer in the neighborhood. They lived there together until another child was forthcoming which the husband refused to own. When finally the farmer acknowledged this child to be his, the same good friends (sic) interfered, went into the courts and procured a divorce from the husband, and had the woman married to the father of the expected fourth child. This proved to be feeble-minded, and they have had four other feeble-minded children, making eight in all, born of this woman. There have also been one child stillborn and one miscarriage.

"... This woman had four feeble-minded brothers and sisters. These are all married and have children. The older of the two sisters had a child by her own father, when she was thirteen years old. The child died at about six years of age. This woman has since married. The two brothers have each at least one child of whose mental condition nothing is known. The other sister married a feeble-minded man

and had three children. Two of these are feeble-minded and the other died in infancy. . . .”⁴

Not alone in her descendants, but also in her ancestry and collateral relatives does this woman illustrate the influence of defective germ plasm in a family. Of twenty-seven children, one or both of whose parents were feeble-minded, twenty-four showed the defect, the character of the other three being unknown.

The following cases cited by Davenport are further examples of the blight which defective inheritance so often casts upon a human life.

This case “is an eleven year old boy who began to steal at 3 years; at 4 set fire to a pantry resulting in an explosion that caused his mother’s death; and at 8 set fire to a mattress. He is physically sound, able and well informed, polite, gentlemanly and very smooth, but he is an inveterate thief and has a court record. His older brother, 14, has been full of deviltry, has stolen and set fires but is now settled down and is earning a living. Their father is an unusually fine, thoughtful intelligent man, a grocer, for a time sang on the vaudeville stage; his mother, who died at 32, is said to have been a normal woman of excellent character. There is however a taint on both sides. The father’s father was wild and drank when young and had a brother who was an inveterate thief. The mother’s father was alcoholic and when drunk mean and vicious. Some of the mother’s brothers stole or were sexually immoral.

“A healthy man employed on a railroad as a fireman and using neither alcohol nor tobacco married a woman who was born in the mountains of West Virginia near the Kentucky line and who shows many symptoms of defectiveness. She has epileptic convulsions as often as two or three times a week, has an ungovernable temper, smokes, chews and drinks, is illiterate and sexually immoral. There are 10 children, of whom something is known about seven. One died early of chorea, one of the others seems normal; one has killed two men including a policeman; another had her husband killed and lives with the slayer; one was an epileptic and cigarette fiend, convicted of assault; another has hysterical convulsions and is afraid in sleep; while still another has migraine. The combination in the fraternity of migraine, chorea, hysteria, epilepsy and sexual immorality and tendency to assault is striking and appalling.

“A 10 year old boy who was precocious as a raconteur at 22 months, does well at school except for inattention; is fond of reading and athletics, cheerful, and polite. But he prefers

“American Breeders Magazine,” Vol. I, pp. 176-8.

the companionship of older, wild boys and cannot be weaned from them. He lies, runs up accounts in his parents' name, is acquiring bad sexual habits, and runs away from home. He has two, fine, studious brothers. His father is a strong character and a successful lawyer, his mother an excellent woman, intelligent and firm. She has a brother who left home at 14 to seek a life of adventure. He finally settled down to a steady life. Their father's father was erratic. He loved Indian outdoor life, always used an Indian blanket and at over 70 years swam the Mississippi River. He traced back his ancestry to Pocahontas. He has another grandson, who is an unruly character with a roving disposition; he joined the navy and his whereabouts are unknown; his father was a lawyer and a fine character.

"An intelligent physician with training abroad as well as in this country and of a good family (his brother is a college professor and his father a Methodist preacher) married a lady of good family, with much musical talent, but subject to migraine and formerly to chorea. They have two sons born in the best of environments. The younger is still in the kindergarten, seems wholly normal, truth-telling and lovable; the other, now 13, developed normally, has had no convulsions, and has never been seriously sick and ordinarily sleeps well. He has regular, refined features and a normal alert attitude and is very industrious. He attends Sunday school regularly, has excellent talent for music. At 3 years of age he walked to a nearby railroad, boarded a train and was carried 12 miles before the conductor discovered him; since then he has run away very many times. From an institution for difficult boys, where he was placed, he ran away 13 times. He escapes from his home after dark and sleeps in neighboring doorways. His mother used to make Saturday a treat day. She would take a violin lesson with him and spend the afternoon in the Public Library which he much enjoyed but he would slip away from her on the way home and be gone until midnight. He is an unconscionable liar. He contracts debts, steals when he has no use for the articles stolen and has been convicted for burglary. Much money and effort have been spent on him in vain. His mother's father (of whom he has never heard) was a western desperado, drank hard and was involved in a murder, but finally married a very good woman, and has 2 normal daughters in addition to this boy's mother."⁵

As examples of the inheritance of physical defects may be cited that of deaf-mutism, hare lip and cleft palate, imperfect

⁵ Davenport, "Heredity in Relation to Eugenics," pp. 85-90. By permission of Henry Holt and Company.

clotting of the blood resulting in the persistent bleeding of wounds, cretinism or infantile imbecility and dwarfism, and many others.

But the picture has also a brighter side, for physical and mental ability are inherited just as surely as are their opposites. The families of the Edwards, the Lees, the Corbins and the Fitzhughs have put the stamp of beauty and of strength upon the face of America. The family of the great musician Bach included twenty eminent musicians, and twice as many of lesser eminence.

Macaulay's father and grandfather, two uncles, a cousin and a nephew were all noted writers. The records of the Pomeroy family date back to 1630. "The first of the family in America was Eltweed Pomeroy at Dorchester . . . and later at Windsor, Connecticut. He was by trade a blacksmith, which in those days comprehended practically all mechanical trades. His sons and grandsons, with few exceptions, followed this trade. 'In the settlement of new towns in Massachusetts and Connecticut the Pomeroyes were welcome artisans. Large grants of land were awarded to them to induce them to settle and carry on their business.' 'The peculiar faculty of the Pomeroyes is not the result of training and hardly of perceptible voluntary effort in the individual. Their powers are due to an inherited capacity from ancestry more or less remote, developed for generations under some unconscious cerebration.' There was Seth Pomeroy (1706-1777) an ingenious and skillful mechanic who followed the trade of gunsmith. At the capture of Louisburg in 1745 he was a major and had charge of more than twenty smiths who were engaged in drilling captured cannon. Other members of the family manufactured guns which in the French and Indian wars were in great demand and in the Revolution, also, the Pomeroy guns were indispensable. 'Long before the United States had a national armory, the private armories of the Pomeroyes were famous. There was Lemuel Pomeroy, the pioneer manufacturer of Pittsburg, stubborn but clear-headed, of whom a friend said: 'There would at times be no living with him if he were not always right.' There was also Elisha M. Pomeroy of Wallingford, a tinner by trade. He invented the razor strop and profited much by its success. In the sixth generation we find Benjamin Pomeroy a successful lawyer entrusted with important public offices. 'But he was conscious of powers for which his law practice gave him no scope. He had a taste for mechanical execution and as a pastime between his professional duties undertook the construction of difficult public works—the more difficult the better he liked them. The chief of the United States

Topographical Engineers was a friend of Mr. Pomeroy and repeatedly consulted him in emergencies wherein his extraordinary capacity was made useful to the government. By him were constructed on the Atlantic coast beacons and various structures in circumstances that had baffled previous attempts.' The value to this country of the mechanical trait in this one germ plasm can hardly be estimated. Especially is it to be noted that, despite constant out-marriages, it goes its course unreduced and unmodified through the generations.'⁶

Well, what is the eugenist "going to do about it?" In the first place gather data upon which to base a constructive program. While our knowledge of inheritance in plants and animals has grown by leaps and bounds in the past twenty years, and data concerning human inheritance are accumulating rapidly, the science of genetics, and especially eugenics is yet in its infancy. Our knowledge of human inheritance is still very fragmentary; comparatively few characters have yet been studied, and these by no means exhaustively. Recognizing information as the primary need of the social student of today, the Eugenics Laboratory in London and the Eugenics Record Office at Cold Spring Harbor are devoting their energies chiefly to a study of the laws of human inheritance, with the ultimate view of formulating from those laws a constructive program of eugenics, supported by a public opinion, alive on the one hand to the menace, and on the other to the splendid possibilities of human inheritance.

But while gathering more information are we to sit idle and not use the information which we have? What can we "do about it" now? First of all, we need more sanity and less self-confidence, more cool calculation and less hot enthusiasm. The advocates of the "rabbit theory" of society, who cry out from the house-tops against the suicide of the race, should realize that propagation is as dangerous as propaganda if the subjects thereof are unworthy or unfit. On the other hand, the advocates of "birth control" should not forget that "a little knowledge is a dangerous thing" and that knowledge of this practise by the selfish, the ignorant or the unwise might prove to be a match in the hands of a child.

The fundamental principle of eugenics is the promotion of a better race by the marriage of the fit, and the elimination of the undesirable members of society by the prevention of their increase. But in a matter of so highly personal a nature as marriage, where personal tastes and emotions play so large a part, how is anything like scientific control possible? The only answer is that it is not possible, nor desirable. If men

⁶ Davenport, *locus citatus*, pp. 55-57.

and women chose their partners as they choose a pet dog or a suit of clothes, the divorce courts would have to work overtime. But on the other hand no one has the right to insure his own temporary happiness at the risk of the misery of those who are to follow him. And here is where eugenics has its major rôle to play—namely, in the education of the youth as to the inflexibility of inheritance, the methods of its operation, and their duty to generations yet unborn.

The rights of the individual form one of the corner stones of a democracy, while those of society, or the group of individuals, form the other. In so far as the former does not conflict with the latter it must be fully insured or democracy becomes an empty name, but no man has a right to personal freedom when that freedom encroaches upon the welfare of society, and one of the functions of eugenics is to preserve that welfare by preventing the increase of the feeble-minded, the alcoholic, the sexually immoral and the diseased—or in general, the unfit. The simplest and safest way in fact, is sterilization. This can be accomplished by a very simple and harmless operation in man, requiring only a few minutes of time and the use of a local anesthetic. In woman it is a more serious operation, but in neither case, if carefully performed, is it dangerous or productive of evil after-effects. Needless to say, the practise of sterilization should be surrounded by every precaution to protect the rights of the individual, and should not be practised except by expert and responsible surgeons. Thus far eleven states have sterilization laws, though but few operations under these laws have as yet been performed. In some instances individuals have voluntarily submitted themselves to the operation.

The first of these to be adopted was the Indiana law, which is here quoted: "An Act, entitled, An act to prevent procreation of criminals, idiots, imbeciles, and rapists—providing that superintendents, or boards of managers, of institutions where such persons are confined shall have the authority, and are empowered to appoint a committee of experts, consisting of two physicians, to examine into the mental condition of such inmates.

"Whereas, Heredity plays a most important part in the transmission of crime, idiocy, and imbecility;

"Therefore, Be it enacted by the General Assembly of the State of Indiana, That on and after the passage of this act it shall be compulsory for each and every institution in the State, entrusted with the care of confirmed criminals, idiots, rapists and imbeciles, to appoint upon its staff, in addition to the regular institutional physician, two (2) skilled surgeons of recognized ability, whose duty it shall be, in conjunction

with the chief physician of the institution, to examine the mental and physical condition of such inmates as are recommended by the institutional physician and board of managers. If, in the judgment of this committee of experts and the board of managers, procreation is inadvisable, and there is no probability of improvement of the mental and physical condition of the inmate, it shall be lawful for the surgeons to perform such operation for the prevention of procreation as shall be decided safest, and most effective. But this operation shall not be performed except in cases that have been pronounced unimprovable: Provided, That in no case shall the consultation fee be more than three (3) dollars to each expert, to be paid out of the funds appropriated for the maintenance of such institution."

The question of elimination of defectives, by preventing their procreation, leads to the delicate one of elimination of human misery by taking the life of children, so hopelessly deformed or diseased, that they can never by any possible chance be anything but sources of suffering to themselves, and of unhappiness to their friends. The practise of destroying those infants considered unlikely to develop into vigorous men, and good soldiers is well known as the policy of Sparta in ancient Greece, and among savages infanticide has sometimes been practised for a similar reason. In India the killing of girl babies to save them the dishonor of remaining unmarried or of marrying below their caste, as well as to avoid the excessive expense incident to marriage ceremonies, was prevalent among many tribes previous to the middle of the last century, when it was terminated by the British Government. Among civilized peoples infanticide is generally regarded as a crime equal to, or but slightly less than murder. Abortion, unless practised to save the life or health of the mother, is criminal, though of a much lower degree than infanticide. The logic of a distinction between a fœtus a few days before birth and a baby a few days after, is somewhat difficult however to appreciate.

The reverence for human life has even extended to the dead body, so that in the early days of anatomy, cadavers for dissection could only be obtained by devious means.

The sacredness in which we hold life has led us to take every means for its preservation, even to abolition in many states and foreign countries of capital punishment, the forcible restraint of attempted suicides, and the most careful nurture of helpless cripples and hopeless idiots. Because of our reverence for human life we sometimes practise the most refined cruelty to those we love the best, a cruelty we would not tolerate for a moment if practised upon the dumb brute.

It was therefore with a feeling akin to horror that many read in the public press in 1915 of the action of Dr. Haiselden of Chicago; who, with the consent of the child's parents, refused to perform an operation which would have saved to a life of suffering, an infant, which by his refusal was allowed to die. This question however is not one of eugenics proper, although closely related thereto. But it is one which the thoughtful student of human life will do well to ponder carefully.

And yet a final duty of the eugenist is to combat those anti-social measures which put a premium on celibacy, and a discount on parenthood, such as the payment of non-living wages to workmen, the industrialization of women, the penalization of teachers for marriage or motherhood. A forward step in the right direction has been the payment by many states of mothers' pensions, while further action should be taken to relieve the mother during the early months of maternity from the necessity of bread winning.

We have come already a long way in the paths of social righteousness, but the way is never-ending and the forces of selfishness, reaction and ignorance beset us on every hand, so that it behooves us to gird up our loins in order that we, like Paul, may "run with patience the race that is set before us."

CHAPTER XI

*Experimental biology continued. Mechanism versus vitalism.
Physico-chemistry of vital processes, metabolism of animals and plants.*

Is there one law for the living and another for the dead, or is the universe a unit in its working and all matter governed by universal law? The former is the contention of the "vitalist," the latter of the "mechanist." What is life? Is it some inscrutable process, controlled by a "vital principle" operating outside the realm of physics and of chemistry? Or is it merely a special expression of the forces which control inorganic matter? Our only answer to these questions is that we do not know. Neither the substance nor the energy of life has ever been analyzed, and the only way in which we can identify life is by its manifestations. What are these manifestations, and what light if any do they throw upon the ultimate nature of life itself?

Firstly, what is the stuff of which living things are made? An analysis of living substances or protoplasm is exceedingly difficult if not impossible. In order to analyze it, it must be killed, and the readiness with which protoplasm breaks down into innumerable simpler substances leads us to suspect that after protoplasm is killed it is protoplasm no longer, so that we are analyzing not protoplasm at all, but something else. Our analyses are sufficient to show us however that protoplasm contains the same elements of which inorganic matter is composed, united into a marvellously complex whole. All life is "of the dust, and turn(s) to dust again." The manifold varieties of life which we know lead us to believe in as great a variety of protoplasm which determines this variability in living things. In spite of its variability however all protoplasm alike contains protein consisting of carbon, hydrogen, nitrogen, oxygen and sulphur, without which it cannot exist. Protein however is found outside of protoplasm in egg albumen for example and in the various albumens and globulins of the blood. These substances while protoplasmic products are not protoplasm itself; hence we see that in its composition at least living matter does not differ fundamentally from non-living, since both contain the same materials.

One of the most characteristic features of life is its power of waste and repair and growth. It is folly to attempt, as some have done, to compare these processes in their entirety with any process in the non-living world. There is nothing with which they can be compared. And yet if we analyze them into their component processes, we find that they are composed of a series of chemical and physical reactions, many of which at least can be exactly reproduced in the laboratory.

In the warm spring days when the remnants of last year's crop of potatoes in the cellar start to sprout, and those which are served upon your table have an unpleasant sweetish taste, you are the victim of a ferment known as diastase, of wide-

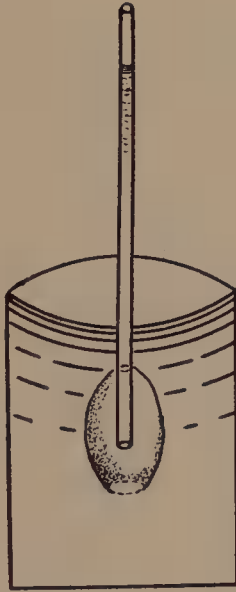


Diagram illustrating osmosis through an egg membrane. Original.

spread if not universal distribution among plants, which changes starch, the stored-up food stuff of the plant, into one of the sugars. When the maple sugar sap is flowing in the spring we know that a similar action has been taking place within the tree, and all the beauty of the young spring's growth depends upon it. A similar action takes place in our own stomach, under the influence of an animal ferment known as ptyalin, and present in the saliva of many mammals. But a similar result can also be obtained in the test tube of the chemist by boiling starch in dilute acid.

In order that the water of the soil with its dissolved salts may enter the root, or the digested food stuffs in the intestine pass into the streams of blood and lymph, the process of os-

mosis, or the passage of solutions through membranes must occur. But if the shell be chipped off from both ends of a hen's egg, the shell membranes being left intact at one end, and the yolk and white removed from the other, into which a glass tube is sealed with a few drops of sealing wax; and if now the egg be filled with a solution of sugar, and then immersed in water, until the water is at the same level with the solution in the tube, the latter will soon be seen to rise due to the passage of water through the egg membrane into the sugar solution; while more slowly the sugar will diffuse in the reverse direction. Here we see in non-living matter the same phenomenon of osmosis, which is so fundamental a factor in all living processes.

In the exchange of materials between the cell and its environment, its membrane determines what substances shall enter and leave the cell. Thus an uninjured beet may be placed in water without losing any of its color. But cut the beet and its color readily diffuses outward. So in the absorption by roots of substances from the soil and by the walls of the intestine from the digested food stuffs, the cell membrane exercises what is known as "selective absorption," taking some and rejecting others. In the passage of substances between mother and child, through the walls of the placenta, the cells of the latter exercise a selective function, allowing food materials and oxygen to pass from mother to child, and waste materials to pass in the reverse direction. This selective activity of living membranes is strikingly shown by experiments on barley seeds, which are not killed by sulphuric acid because it cannot penetrate them, but are destroyed by bichloride of mercury, which readily enters.

In the burning coal of the furnace and in the forest's decaying logs, one of the final products of combustion or decay is carbon dioxide. So too when we exhale the carbon dioxide from our lungs we are casting off one of the end products in the combustion or oxidation of our foods and our tissues.

Throughout the entire process of metabolism, of growth, repair, decay, the body of animal or plant is a physico-chemical laboratory in which are taking place the processes of the non-living world.

Another characteristic feature of living things is their power of movement. This is not evident at first sight in all organisms, notably plants. In fact, one of the criteria formerly presented as distinguishing plants from animals was the fixity of the former as compared with the motility of the latter. This distinction we now know to be false however, for even in the apparently non-motile plants there is circu-

lation of cell sap, and movements of leaves and roots in response to stimuli; while among animals, the attached forms such as sponges, sea anemones, barnacles, etc., either lack locomotive power or possess it in very slight degree.

All living things then are motile to greater or less degree. But is this quality lacking in the non-living world? Place a diluted drop of ink under the microscope and it becomes a microcosm of violent activity. Wind and water are ever active. The earth is flying through space at the rate of $18\frac{1}{2}$ miles a second, and the universe is a realm of eternal motion. Light and sound are expressions of movement, and the electronic theory of matter postulates that matter itself is a cosmos of ceaseless energy. But the vitalist tells us that living matter possesses "spontaneity," which is lacking in the non-living world. The living thing moves of its own "volition," the non-living only under the influence of forces external to itself. But what evidence have we of "volition" on the part of an *Amœba* or bacterium, while the energy of the living machine is as truly the result of oxidation of fuel as is that of the steam turbine or the automobile. Any distinction then on the basis of motion alone between the world of the living and the non-living is a fallacy.

Adaptation is one of the most characteristic features of life. The bird and bat are adapted for flight, the fish for swimming, the monkey for climbing: one need not enumerate, for one cannot name a single living thing which is not adapted to the conditions of its existence; otherwise it would not exist. Adaptation is the very keynote of life, and the tablets of the past are crowded with the records of creatures, which, serving well their day and generation, failed to adapt themselves to changing conditions, and so were trampled under foot by the onrush of the fit in the bitter struggle for existence.

But are living things alone adapted to their environment? Does not the river adapt itself to its channel, the lake to its basin, and the gas to the form and size of its container? Ice exists in winter because it is adapted to the cold and disappears in summer because it is not adapted to the heat. Adaptation indeed is merely an expression of action and reaction, of cause and effect. But, argues the vitalist, these are merely examples of the direct physical influence of one thing upon another, while life adapts itself only in indirect and as yet unknown ways. The fact of adaptation in the inorganic world remains however, and when the riddles of life have been solved it is not unlikely that the process of adaptation of living things can be resolved into simple physico-mechanical terms, just as surely as can the adjust-

ment of the river to its channel, or the snow drift to the wind.

Yet another manifestation of life is its irritability or power of response to stimuli. Examples of this are so common that it is merely trite to repeat them. There is no form of life so primitive or so sluggish as to escape this universal law. But is this phenomenon limited to life alone? Does not lifeless matter also respond to stimuli, or changes in its environment? Examples of such changes must occur to the mind of everyone—changes in volume or in state, whether solid, liquid or gaseous, in response to changes in temperature or pressure, are among the most familiar instances of these responses. If a metal be heated its electrical conductivity is decreased, sound travels faster the higher the temperature, while atmospheric conditions will materially affect the messages flashed from the wires of the radio. While the responses of living things and changes in their environment are infinitely more complex and indirect than are those of the non-living, yet the same principle holds true for both, and when we know more of the mechanism of life it may be possible to resolve its complex reactions into their simpler terms.

Yet one great characteristic of life remains, namely, reproduction. The development of a human being with his myriad cells, more varied in form than the manifold parts of the most complicated machine, ranging in size from the tiny corpuscles of the blood, less than one four-thousandth of an inch in size, to the motor nerve cells of the spinal cord, which may reach a length of over three feet; and including the intricate structures of the brain by which are performed all the wonderfully complex functions of the human body, including the as yet inscrutable processes of thought; all these coming from an apparently simple cell a little more than one one-hundredth of an inch in size, is a wonder beside which the magic of an Aladdin or the miracles of holy writ fade into ghostly paleness. The enthusiast in the ranks of the mechanists has attempted however to remove even this most distinctive feature of living things, by showing that non-living matter may in a certain sense reproduce itself, as new crystals form in an evaporating salt solution. However feeble such a comparison may be, it is nevertheless true that all phases of reproduction—the growth of the germ cells, their union, the entrance of the spermatozoon, the division of the fertilized egg, the growth and differentiation of the tissues are all intimately associated with physico-chemical changes taking place in these cells, and can, as we shall see later, to a certain extent at least be induced by artificial means.

Whatever the answer to the riddle of life may ultimately be it is at least certain that our present most hopeful line of attack lies in the, at least partially known, fields of physics and chemistry, rather than in the unknown metaphysical one of "vital principles," "entelechies" and other hypothetical factors. What information then does the bio-chemist have to give us which may help us in the solution of our problem?

The writer once accompanied a class of school-boys through a Colorado mine. On the mine track stood a string of empty cars, and one of the boys asked the conductor of the party what kind of fuel they used for their engines in the mine. "Hay," replied the conductor, which somewhat puzzled the boys, until they learned that mules furnished the motive power for the cars. One of the earliest speculations of physiologists was regarding the nature of animal heat. Some animals (birds and mammals) have a constant body temperature which is usually higher than that of their surroundings. "What is this heat, and whence does it come?" the early investigators asked themselves. It was at first supposed that heat was a substance which entered and left the body in some unknown way. Toward the beginning of the eighteenth century speculation began to call experiment to its aid, and Mayow, Boyle and Priestley tried keeping small animals in closed chambers, with the result that they soon died. They also tried introducing lighted candles into similar chambers and found that just as the "flame of life" was soon extinguished, so too the candles went out, if denied air. They further found that an animal could not live so long in a jar in which the air had been exhausted by a burning candle as in one in which the air was fresh; and *vice versa* the candle would not burn where an animal had exhausted the air before it, nor would one animal live as well in a chamber formerly occupied by another, or one candle burn as well where another had been previously burned, as in one containing air which had not been used up previously. These experiments led them to suspect that the breathing of the animal and the burning of the candle were similar processes.

Soon after followed Priestley's discovery of oxygen which he called by the sophisticated title of dephlogisticated air, from the Greek word *phlogiston* or inflammable. Now followed Lavoisier's discovery that when a candle was burned, or an animal breathed, the oxygen or dephlogisticated air of Priestley, which formed one-fifth of the volume of ordinary air, was converted into what was formerly known as "fixed air," a compound of carbon and oxygen. Lavoisier now assumed that the heat of the animal body was produced in a manner analogous to that of the burning candle, namely

by the combustion of the carbon in the body, or its union with oxygen to produce carbon dioxide. In support of this assumption he pointed out that in birds, whose temperature is higher than that of mammals, there is a greater production of carbon dioxide in respiration.

To test this hypothesis Lavoisier constructed a primitive calorimeter for measuring the heat production of the animal body. This consisted essentially of two chambers, an inner, for holding the animal whose heat production was to be measured, and an outer of double walls, the space between which, as well as that of the outer chamber itself, was packed with ice. Knowing the amount of heat required to melt a given quantity of ice, and measuring the carbon dioxide and water produced by the animal, it should be possible to determine whether the respiration of the animal was of the proper amount to account for the heat produced. Without going into details regarding these experiments of Lavoisier, and his successors Dulong and Depretz, it is sufficient to say that the results of these early experimenters showed a very close correspondence between the heat calculated from the respiratory products formed, and the actual production of heat in the calorimeter and led to the conclusion established by later observers that the production of energy in the animal body is dependent on the oxidation of the food consumed, and further that conservation of energy is just as true of the latter as of any non-living machine.

The work of these early experimenters has been continued in recent years by Benedict and Atwater at the Nutrition Laboratory of the Carnegie Institution in a series of brilliant investigations with the aid of a very ingenious and intricate respiration calorimeter. This in brief consists of a chamber large enough for a man to live in for several days at a time, and containing apparatus (i. e., a bicycle) on which exercise may be taken. The chamber is constructed of a double metal wall with a contained air space and is surrounded with a double wall of wood containing a second air space, while between metal and wooden walls is an intermediate air space, the whole very effectively preventing any exchange of heat between the interior and exterior of the chamber. As a further precaution to prevent such exchange of heat special electrical devices are installed for keeping the two walls of the metal chamber at the same temperature, and any difference in temperature between them is recorded on a galvanometer on the observer's desk in the laboratory. Connected with the chamber are various devices for measuring the intake of oxygen, the outgo of carbon dioxide and water, the heat lost by the subject during the experiment and the amount of

energy expended in muscular activity. To illustrate the extreme care taken to avoid error in the use of this apparatus may be cited the precautions used in measuring the amount of heat generated by the subject in the calorimeter. This is determined by reading the temperatures of a stream of water which circulates through coils of pipe in the chamber. To the ordinary person it would seem as though it were sufficiently accurate to read these temperatures as given by accurate thermometers. But in order to eliminate all possible error corrections are made for the effect of pressure of water on the bulb of the thermometer. Within the chamber is a folding cot, chair, table and other conveniences. During an experiment the entrance to the chamber is tightly sealed by glass which serves as a window, while a small opening serves for exchange of food, water, excreta, etc. A telephone enables the occupant to talk to persons on the outside. The apparatus is so delicate that the slight rise in temperature caused by the subject rising from his chair is recorded by it.

The respiration calorimeter is used for investigating the many intricate problems of human nutrition and especially for determining the relation between different kinds of food and the energy furnished by them. To test its accuracy its designers performed a series of check experiments in which alcohol instead of human tissue was burned, and the amounts of carbon dioxide, water and heat produced, and oxygen consumed, were measured and compared with the amount required by calculation from the amount of alcohol used. Four such experiments showed an average difference between the calculated and experimental results of less than one-half of one per cent.

Experiments with the calorimeter can be made to show what proportion of the energy available in the food consumed is used in the work done by the subject. It is a fact well known to all mechanical engineers that no machine can utilize all the energy of its fuel. This is largely due to loss of heat by radiation from the surface of the machine and in friction. Our best engines can use perhaps not more than one-tenth of the energy available in their fuel. In this respect the human machine is a more perfect mechanism, for it can use about 15-20% of the energy available in its fuel (food) for mechanical (muscular, nervous, etc.) work.

The subject of human nutrition is one to fill volumes in itself. We can only note here in passing a few of the most interesting and important results obtained from experiments in this field.

Two of the perquisites which the Englishman of past generations has regarded as his inalienable right have been

his meat and his ale, and his descendants on this side of the water have maintained fairly well the reputation of their ancestors. But "those who dance must pay the fiddler" and high living has brought in its train not only high grocer's, but high doctor's bills and mortality rates as well. The advent of meat cards and meatless days during the war brought about a cut in the size of our steaks if not of our butcher's bills. If this seeming privation teaches us that an excessive meat diet is not essential to our health and happiness the game will indeed prove "worth the candle." But there were even in early days voices raised in warning against prevalent excesses in diet. One of these was the plea for moderation in eating by the English physician Thomas Cogan, published in 1596 under the title "*The Haven of Health*," in which he says: "The second thing that is to be considered of meates is the quantitie, which ought of all men greatly to be regarded, for therein lyeth no small occasion of health or sickness, of life or death. For as want of meate consumeth the very substance of our flesh, so doth excesse and surfet extinguish and suffocate naturall heat wherein life consisteth." Again, "Use a measure in eating, that thou maist live long: and if thou wilt be in health, then hold thine hands. But the greatest occasion why men passe the measure in eating, is varietie of meates at one meale. Which fault is most common among us in England farre above all other nations. For such is our custome by reason of plentie (as I think) that they which be of abilitie, are served with sundry sortes of meate at one meale. Yea the more we would welcome our friends the more dishes we prepare. And when we are well satisfied with one dish or two, then come other more delicate and procureth us by that means, to eate more than nature doth require. Thus varietie bringeth us to excesse, and sometimes to surfet also. But Phisicke teacheth us to faede moderately upon one kinde of meate only at one meale, or at leastwise not upon many of contrarie natures. . . . This disease, (I mean surfet) is verie common: for common is that saying and most true: That more die by surfet than by the sword. And as Georgius Pictorius saith, all surfet is ill, but of bread worst of all. And if nature be so strong in many, and they be not sicke upon a full gorge, yet they are drowsie and heavie, and more desirous to loyter than to labor, according to that old master, when the belly is full, the bones would be at rest. Yea the minde and wit is so oppressed and overwhelmed with excesse that it lyeth as it were drowned for a time, and unable to use his force."¹

¹ Quoted from Chittenden, "*The Nutrition of Man*," pp. 166-7.

In recent times physiologists, both pseudo and scientific, including a great variety of cranks of all sorts and sizes, have been turning their attention more and more to matters of diet, and the layman is beginning to learn that it is possible for him to select his food, not only with respect to price and palatability, but also for its value as a fuel for the human machine. The principal elements in human diet are proteins (meat, eggs and, to a less extent, milk, grain and vegetables), carbohydrates (sugar and starch) and fats. One of the greatest services rendered by modern students of human nutrition has been to show that a high protein diet is not only unnecessary, but actually in many cases detrimental to health. Studies of this sort have been largely conducted in this country by Professors Chittenden and Fisher at Yale, the results of two of the most striking of whose experiments are here summarized. The first of these was conducted upon a group of thirteen United States soldiers, for a period of six months, and the second on eight college athletes for five months.

The ordinary diet of the soldiers prior to the experiment may be illustrated by the following average day's menu:

Breakfast—Beefsteak 8 oz., gravy 2.4 oz., fried potatoes 8.2 oz., onions 1.2 oz., bread 5 oz., coffee 24 oz., sugar 0.6 oz.

Dinner—Beef 6 oz., boiled potatoes 12.3 oz., onions 2 oz., bread 8.2 oz., coffee 32.3 oz., sugar 1 oz.

Supper—Corned beef 6.9 oz., potatoes 6 oz., onions 0.7 oz., bread 5.5 oz., fruit jelly 3.7 oz., coffee 15.0 oz., sugar 9.7 oz.

During the experiment the amount of meat was gradually reduced until the men were living on a diet of which the following day's menu is a sample:

Breakfast—Wheat griddle cakes 7 oz., syrup 1.7 oz., one cup coffee, with milk and sugar, 12.3 oz.

Dinner—Codfish balls (4 parts potato, 1 part fish, fried in pork fat) 5.3 oz., stewed tomato 7 oz., bread 2.6 oz., one cup coffee 13.3 oz., apple pie 3.3 oz.

Supper—Apple fritters 7 oz., stewed prunes 4.4 oz., bread 1.7 oz., butter 0.4 oz., one cup tea 12.3 oz.

As a result of this change of diet some of the men showed a slight loss of weight which occurred at the start, and in others an actual gain for the entire period. In only one case, that of a stout man, was there any noticeable decrease, which in his case was to his advantage, rather than the reverse.

Not only was there no harmful loss of weight, but the general health was maintained and in some cases improved. "Most conspicuous, however, though something that was entirely unlooked for, was the effect observed on the muscular strength of the various subjects," which showed not a loss, but on the contrary a decided gain, "and furthermore," says

Professor Chittenden, "there was a noticeable gain in self-reliance and courage in their athletic work, both of which are likewise indicative of an improved condition of the body. How far these improvements are attributable to training and to the more regular life the men were leading, and how far to the change in diet, cannot be definitely determined. We may venture the opinion, however, . . . that the change in



A SOLDIER AFTER A SIX-MONTHS' DIET LOW IN MEAT

After Chittenden, "The Nutrition of Man."

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diet was in a measure at least responsible for the increased efficiency. As the writer has already expressed it, there must be enough food to make good the daily waste of tissue, enough food to furnish the energy of muscular contraction, but any surplus over and above what is necessary to supply these needs is not only a waste, but may prove an incubus, retarding the smooth working of the machinery and detracting from the power of the organism to do its best work."

Concerning the second experiment above mentioned Professor Chittenden says: "Here, again, we see that a relatively small intake of proteid food will not only bring about and maintain nitrogen equilibrium for many months, and probably indefinitely, but that such a form of diet is equally as effective with vigorous athletes, accustomed to strenuous muscular effort, as with professional men of more sedentary habits. Further, these many months of observation with different individuals all lead to the opinion that there are no harmful results of any kind produced by a reduction in the amount of proteid food to a level commensurate with the actual needs of the body. Body-weight, health, physical strength, and muscular tone can all be maintained, in partial illustration of which may be offered two photographs of one of the eight athletes taken toward the end of the experiment; pictures which are certainly the antithesis of enfeebled muscular structure, or diminished physical vigor."

Similar results have been obtained with professional men. Altogether they show very conclusively the possibility of not only maintaining, but also of improving human health with a diet relatively low in proteid matter.

What now will be the result if an animal, which in its natural state was exclusively carnivorous, and even in domestication is still largely so, be fed on a proteid-poor diet? Some of the earlier experimenters in Europe found that a reduction in the meat of a dog's diet resulted in gastrointestinal disturbance followed by death. These experiments however were conducted with dogs kept in close confinement and as Chittenden says "It is doubtful if there is full appreciation of the possible effect of monotony, in the ordinary dietary experiments on dogs. Man quickly feels the effect; the sportsman camping in the woods by brook or lake enjoys his first meal of speckled trout and has no thought of ever becoming tired of such a delicacy; but as trout cooked in various ways continue to be placed before him three times a day, and with perhaps very little else, he soon passes into a frame of mind where salt pork would be a luxury, and where he would prefer to go hungry rather than eat the delicacy, if indeed he has appetite to eat anything. Is it strange that dogs confined in cages barely large enough to permit of their turning around, and fed day after day and month after month with exactly the same amount of desiccated meat, fat, and rice, should show signs and symptoms, if nothing worse, of disturbed nutrition? It is necessary in experiments of this kind that the animals be confined for given periods, at least. . . . It is possible, however, to limit the time of close confinement to, say, ten consecutive days, this to be followed

by a like period of comparative freedom, thus insuring opportunities for an abundance of fresh air and exercise."

In order to test the effects of a proteid-poor diet on dogs living under conditions as nearly ideal as possible a series of experiments were carried out on some twenty animals, some of these lasting an entire year. "All of the . . . dogs . . . were fed on a mixed diet, with some fresh meat each day; bread, cracker dust, milk, lard, and rice being the other foods drawn upon to complete the dietary. The animals were fed twice a day, each meal being accurately weighed and of definite chemical composition. A large, light, and airy room, kept scrupulously clean, and in the winter time properly heated by steam, served as their main abiding place. In this room were a suitable number of smaller compartments, the walls of which were composed of open lattice work (of iron), so as not to interfere with light or air, and yet adequate to keep the dogs apart. These compartments were not cages in the ordinary sense, but were truly large and roomy. . . . In pleasant weather, immediately after their first meal, the dogs were taken out of doors to a large enclosure near by, where they were allowed perfect freedom until about four o'clock, when they were taken in for their second meal (between four and five o'clock in the afternoon). The outdoor enclosure was inaccessible to every one except the holder of the key, and the dogs while there were wholly free from annoyance. Once every month, during a period of ten consecutive days, each dog was confined in the metabolism cage so as to admit of the collection of all excreta, in order to make a determination of the nitrogen balance. Practically, therefore, each dog was in close confinement only one-third of the month, the remaining two-thirds being spent in much more congenial surroundings."

While details regarding all of these experiments cannot be given here one case may be selected as an example. "The animal employed in this experiment . . . was apparently full grown, but was thin and had the appearance of being underfed. At first, it was given daily 172 grams of meat, 124 grams of cracker dust, and 72 grams of lard. . . . (Later) a radical change was made in the diet, by reducing the amount of meat to 70 grams daily; . . . the cracker dust and lard being kept at essentially the same levels as before . . . the dog in the meantime gaining in body-weight. . . . In this manner, the experiment was continued with frequent changes in the character of the diet, but always maintaining essentially the same (food) values . . . (for) just eleven months, with the animal at the close of the experiment still gaining in body-weight, . . . and with every indication of good health and

strength." The results of his entire series of experiments led Chittenden to the conclusion that: "These experiments on the influence of a low proteid diet on dogs, as a type of high proteid consumers, taken in their entirety, afford convincing proof that such animals can live and thrive on amounts of proteid and non-nitrogenous food far below the (usual) standards. . . . The deleterious results reported by these investigators were not due to the effects of low proteid or to diminished consumption of non-nitrogenous foods, but are to be ascribed mainly to non-hygienic conditions, or to a lack of care and physiological good sense in the prescription of a narrow dietary not suited to the habits and needs of this



EFFECT OF DIET ON DOGS

LEFT—A dog fed on a diet containing one-half pound of meat daily.

RIGHT—The same animal after several months on a diet with less than half as much meat. From Chittenden, "The Nutrition of Man."

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class of animals. Further, it is obvious that the more or less broad deductions so frequently drawn from . . . experiments (on dogs) . . . especially in their application to mankind, are entirely unwarranted and without foundation in fact. Our experiments offer satisfying proof that not only can dogs live on quantities of proteid food per day smaller than (are usually) . . . deemed necessary, and with a fuel value far below the (usual) standard . . . ; but, in addition, that these animals are quite able on such a diet to gain in body-weight . . . , thereby indicating that even small quantities of food might suffice to meet their true physiological requirements.

"The results of these experiments with dogs, which we

have recorded in such detail, are in perfect harmony with the conclusions arrived at by our experiments and observations with man, and serve to strengthen the opinion, so many times expressed, that the dietary habits of mankind and the dietary standards based thereon are not always in accord with the true physiological requirements of the body."

There is one experiment in the foregoing series regarding which a further word may be said. In this experiment a dog which had been fed on a diet of meat, milk, bread and lard was changed to a diet of bread and lard only, the food and fuel value however of the diet remaining unchanged. "In four days' time however a change began to creep over the animal; the appetite diminished, and there was apparent a condition of lassitude and general weakness which deterred the animal from moving about as usual.

"During the next week the animal grew steadily worse, and would eat only when coaxed with a little milk or with bread softened with milk, the diet of bread and lard being invariably refused. There was marked disturbance of the gastro-intestinal tract; bloody discharges were frequent; the mucous membrane of the mouth was greatly inflamed and very sore; body-weight fell off, and the animal was in a very enfeebled condition. This continued until December 4, with every indication that the animal would not long survive, but by feeding carefully with a little milk and occasionally some meat, improvement finally manifested itself, and by December 18 there was good appetite, provided bread was not conspicuous in the food. Body-weight . . . was . . . slowly regained (until finally) . . . in general condition there was nothing to be desired." ²

Similar results have been obtained by Hopkins and Nevill who kept twenty-four young rats on a diet of protein, starch, lactose (milk-sugar) and salts. They ate well and took sufficient food to supply them with needed energy, but soon ceased to grow and in a few days actually began to lose weight, fourteen of them dying in forty days. With six of the rats there was added to the diet, after the decline in weight had commenced, a small portion of milk daily, which was followed by an immediate improvement in health, and renewed growth.

There are certain problematical diseases in man, which may be due to a lack of something in the food. Beri beri, a disease common among Filipinos, Japanese and East Indians, and characterized by paralysis, swelling and degeneration of the muscles, has been attributed to an extensive diet of

² The foregoing quotations are from Chittenden, "The Nutrition of Man," pp. 187 et seq., by permission of Fred'd A. Stokes Co.

polished rice which lacks the reddish husk of the kernel. If fowls are fed on an exclusive diet of this they die after some weeks. If fed on unpolished rice, they do not contract the disease, and if an extract of the husk or bran be injected into fowls ill from eating the polished grain they will recover. Similarly men who eat the unpolished rice are not subject to beri-beri. It seems then that the rice husk contains some substance which is essential to life.

Pellagra, a disease common among the poorer classes in tropical and sub-tropical countries practically throughout the world, is characterized by weakness, pains, digestive disturbances, skin eruptions and mental disorders, terminating in insanity and finally death. In its earlier stages the disease is recurrent, appearing each spring for several years with increasing severity until it becomes a permanent condition. It has been ascribed to a too extensive diet of corn or to eating spoiled corn. It has also been laid at the door of the villains of so many sanitary (or insanitary) tragedies—the insects. One investigator has recently attempted to find an hereditary basis for the disease. Whatever the ultimate cause it is clearly a disease of disturbed metabolism, and evidence is accumulating to show that imperfect diet is responsible.

Scurvy has long been known as a disease of mal-nutrition, common especially among sailors, who were forced to live on a diet largely of salt meat, so that in the maritime laws of many nations captains were required to furnish their seamen with a ration of vinegar, lime juice or other acid as a preventive.

While the subject of human nutrition is yet in its infancy, especially as regards our knowledge of these problematical substances, which are essential to health, and to some of which, especially those present in milk, the term *vitamine* has been applied; the evidence is clear that to furnish the living machine with the fuel needed for its proper working, it is not sufficient merely to supply the necessary material for energy, repair and growth, but that other things are needed to enable it to properly utilize this fuel. While therefore excesses in eating are but little if any less injurious than those in drinking or other indulgence, there is no place in the régime of the sane and normal individual for the dietary fads and foolishness which some enthusiasts have advocated with great éclat. While most of us undoubtedly eat too much meat, there is small excuse for adopting a strictly vegetarian diet. Our teeth are made for service, and not for the exclusive benefit of the dentist, but while thorough mastication is undoubtedly essential to a ripe old age with good digestion, most of us will hardly find it necessary to chew by the stop-

watch, or to regulate our bites as we do our setting-up exercises. In the feeding of hens for egg productivity Pearl has shown that hens with a mixed diet, from which they were permitted to choose at will, maintained better health than those limited strictly to certain articles. "Reason in all things, excess in none," is a fundamental rule for sanity in diet as in other of our life activities.

What of the mechanism whereby this wonderful machine of life utilizes its fuel? Herein lies one of the fundamental differences between the living and the non-living machine. Whereas the latter uses its fuel solely in the conversion of potential energy into heat and work, the former, in addition to these two functions, also converts some of its fuel into its own substance to take the place of worn-out parts, and to build new parts and enlarge those already formed in development and growth. We have already seen that the living engine is much more efficient in the conversion of the potential energy of its fuel into work than is the non-living machine. How convenient it would be if the latter like the former were automatically repaired as it wore out! Given a good machine to start with, proper fuel and draft, and preventing anyone from throwing in dirt (disease) and the living machine will run without repair for the time of its natural life.

How is this done? In the non-living machine the process of converting fuel energy into work energy is comparatively simple. The carbon of the fuel is in such shape that it can be more or less directly oxidized to carbon dioxide, and heat energy thereby released. But in the utilization of the food or fuel of the living machine a large number of intermediate steps are necessary, which steps often consist of a cycle of changes which are partly degenerative (breaking down complex substance and thereby releasing energy) and partly constructive (building up simpler into more complex substance and storing energy thereby). The food as taken into the body of most animals is in such shape that it cannot be directly burned to furnish energy³ or built up into body substance. While our knowledge of the many complicated changes undergone by food stuffs in the animal body is as yet very meagre, we have nevertheless enough information to enable us to follow in a general way these changes. Probably the food most readily convertible into energy is fat. Some fat is an exception to the statement made above that food is not directly convertible into energy. The Esquimaux use seal blubber both as food and fuel for heating their igloos,

³ I refer here to ordinary conditions of combustion. Any food substance may be burned in a special apparatus known as a bomb calorimeter and its energy content thereby determined.

and various vegetable oils can be burned in a lamp. When taken into the digestive tract however the fat is not usable as fuel any more than any other food substance, but must first undergo digestion.

The function of digestion of all food is to put it into such shape that it can be absorbed by the blood and lymph through the walls of the digestive tract. This transfer or absorption of the food through the latter takes place, as we have seen, by a process of osmosis. The food as eaten is not ordinarily in solution and cannot be passed through a membrane or dialyzed, the function of digestion being to render it soluble and dialyzable. This is accomplished by a process known as hydrolysis which consists in the splitting up of the food into simpler compounds by the addition of water. This process is effected by means of certain remarkable substances formed by all animals and plants and known as enzymes or ferments. When a little yeast is added to a solution of sugar and certain salts and kept at a proper temperature, bubbles of gas (carbon dioxide) soon begin to rise to the surface of the solution. The sugar is being broken down into two simpler substances, carbon dioxide and alcohol, by the ferment secreted by the yeast cells. So far as we know the ferment itself does not change, but acting as by magic affects a change in certain substances with which it comes in contact. Yet even this remarkable activity of the living cell has its counterpart in inorganic nature. If hydrogen and oxygen be brought together at ordinary temperatures there is "nothin' doin' "—to use the English language up to date. But introduce a little finely divided platinum into the situation, and under its seemingly magic influence combination occurs and drops of water form where before there was but gas. The heat generated by this reaction soon raises the platinum to a red heat and this principle was employed in the construction of a self-lighting lamp, in which a jet of hydrogen played upon a bit of spongy platinum, which soon heated—igniting the gas. The platinum here is known as a catalyzer. Its action is similar to that of the ferment since it in some way brings about a change in other substances, without itself entering into that change. The activity of the ferment-forming cell is responsible to itself for its continuation, for when the products of ferment action become too great this action ceases, and will not recommence until these products are removed, or at least lessened in amount.

Among vertebrate animals the digestive ferments are formed chiefly by the stomach, pancreas and intestine, although the liver, and in some instances the mouth glands play a minor part; while the simplified and soluble (digested)

food stuffs are absorbed mainly at least by the walls of the intestine, whence they are carried by the body fluids (blood and lymph) to the tissues of the body, where probably under the influence of other ferments they are again built up into complex substances, which compose the protoplasm of the body cells.⁴ Thus the kernel of the wheat, or the muscle of the beef, is in some mysterious way transformed into the muscle and the nerves, the blood and bone of the animal which consumes them. The various steps in the digestive and absorptive processes are extremely complicated and their character is not fully understood. The large number of products formed in the digestion of the proteid molecule form one evidence of the complex nature of protoplasm. Leaving out of consideration the simpler processes of digestion of starch, sugar and fat, and dealing with proteid digestion alone; passing over also the many and complicated stages in the journey of the proteid molecule through the digestive tract, we come to the end products of digestion, the amino-acids or "building stones of proteid," as they have been called. These amino-acids include a large number of substances, all built around the common nucleus of NH_2 . With these as a basis the constructive ferments of the body build up its marvelously complex materials.

A comparison of the animal body with a machine, the food of the former corresponding to the fuel of the latter is only partially exact, for in the machine, as we have seen, the fuel is directly consumed to furnish energy, while in the animal the change of food energy into work energy is effected in part only through the medium of the body substance itself. After the conversion of the digested food stuffs into the protoplasm of the body this must in turn be broken down through the action of the oxydizing, or destructive ferments, into a whole series of decomposition products, of gradually decreasing complexity, the principal end results being carbon dioxide and urea.

Some of the food stuffs, notably those with the highest energy content, the fats and carbohydrates, and to a less extent the proteids also, may after digestion be directly oxidized to furnish energy; or may in the case of fat and glycogen be stored by the body as a reserve supply for future need. Thus a hibernating animal, such as a bear, during the summer lays up for himself a bountiful supply of fat upon which to draw during the long winter's fast. This storage of energy in the form of reserve food stuffs by the living

⁴Such a brief statement as the above naturally overlooks the many intermediate steps in this very complicated process.

machine finds a parallel in the storage of electrical energy in a storage battery.

Turning from the world of animals to that of plants, we find in the latter a parallel to all of the metabolic processes of the former. The average person is accustomed to think of a plant in terms of the green thing which he finds in garden, field or forest. But when we go a-hunting mushrooms, or poke aside the rotting remains of a fallen tree, we discover other plants which live a different sort of life from that of tree or shrub or herb. And should we delve yet further into Nature's recesses, and penetrate that hidden world to which the microscope gives entrance, we should discover creatures concerning whom no one can say whether they are plant or animal. Some of these uncertain forms are claimed by both botanist and zoölogist as belonging in their own especial field of study, for in some respects they are distinctly animal, in others plant in nature, as we have already seen in an earlier chapter. But while one stands at the portals of life in a realm which is neither plant nor animal; advancing into either kingdom he must follow ever more widely diverging paths; until when he reaches the farthest bounds of this wonderful world he finds its two kingdoms, while governed by the same fundamental laws, nevertheless differing profoundly in their expression.

Perhaps the most fundamental difference between the higher plants and animals is in their metabolism. While the latter are spenders, the former are hoarders of energy, taking raw materials, carbon dioxide from the air and water from both air and soil, and from these constructing by the energy of the sun, acting through the green chlorophyl of leaf and stem, their own food-stuffs; thereby converting the radiant energy of sunlight into the chemical energy of sugar and of starch. From the soil and air the plant obtains its nitrogen, and from the soil the other inorganic substances which it needs to build its protoplasm, and combining these in some as yet but little understood way, with the sugar, by the action of constructive ferments, it builds up its protoplasm. This is what is happening in the blade of grass, the spreading leaf and the stagnant pool, covered with a thick green scum, a little chemical laboratory, where Nature is busily at work making sugar and releasing oxygen. Some day perchance the chemist, imitating Nature, will learn to make our starch and sugar for us, and bid defiance to the "man with a hoe." This indeed is the possibility, perhaps not immediate, but none the less ultimate, of the studies on photosynthesis now under way at the Desert Botanical Laboratory of the Carnegie Institution at

Tucson, Arizona, whose work we have considered in a previous chapter. Synthetic chemistry may well doff its hat and bow low before the greatest creative chemist in the world—the green plant.

The world today hungers and thirsts after nitrogen. We must have nitrogen to fertilize our fields, in order that we may not starve, and we must have nitrogen to rend asunder the bowels of the earth and lay bare the treasures hidden therein, and we must have nitrogen that we may slaughter our fellow men. So we have cleaned the guano beds of Chile, where the sea fowl have been laying down treasure and stench for years untold. We have dug deep into the nitrate beds of Chile and Peru, and today we are harnessing the waterfall and bidding it harvest for us the nitrogen of the air. Meanwhile the silent plant has been putting man's ingenuity to shame, and in its laboratory working wonders, whereat science well may marvel. Truly should man "consider the lilies of the field."

But the green plant is not unassisted in the wonders which it works. On the roots of plants of the pea family occur little swellings or "nodules" which are formed by bacteria which have the power of extracting the nitrogen from the air in the soil and using it to build their own bodies. Hence they are known as the "nitrogen-fixing" bacteria. As these bacteria die they give to the soil compounds of the nitrogen which they have taken from the air. Thus it is that peas and their relatives such as beans and alfalfa are such valuable plants for crop rotation, for if a soil from which the nitrogen has been largely exhausted by continuous cropping with grain be planted for a year or two to beans or alfalfa, the nitrogen-fixing bacteria on the roots of the latter will replace the nitrogen and give to the worn-out soil a new lease of life. But what share does the bean or the alfalfa and the bacteria have in this co-operative association? The latter during their life probably absorb sugars and other substances formed in the leaves of the former and passed down into the roots, while on their death some of the nitrogenous material formed by the bacteria is absorbed by the green plant. The heirs to the riches laid up by these two industrious partners are the plants which follow the peas, beans or alfalfa in rotation. There are other soil bacteria which aid the farmer by changing the ammonia in the soil into nitrites and nitrates, in which form it becomes available as food for the green plants, while *vice versa* other soil bacteria perform exactly the reverse operation and change nitrites and nitrates into ammonia. All life is a cycle. No sooner does one agency build up than

another tears down, and so it goes, in the lives of the unseen bacteria of the soil, as well as in the affairs of man.

But while most animals and plants differ so widely in their metabolism, fundamentally their ways of life are alike. Both must have food, from the combustion of which their energy is derived, and from which their wastage is replaced and growth material obtained. And this food must be rendered soluble and dialyzable in order that it may pass through membranes which surround each cell, i. e., must be digested. While in the higher animal there is a special place where digestion and absorption occur (the digestive tract) and the digestive ferments are formed by special glands (liver, pancreas, etc.), in the plant there is no such specialized tract or glands for the functions of digestion and absorption, these taking place generally in the leaves. There are however certain specialized tubes of cells in the root and stem which taken together form "conducting paths," for the water, with its dissolved salts ascending from the soil, and the sugar descending from the leaves to root and stem, there to be stored as starch for future use. And after digestion the food must circulate through the plant to all its parts, and be built up into its tissues by constructive ferments analogous to those of animals.

In this circulation of water with its dissolved substances through root and stem we see one of those marvelous, and as yet inexplicable phenomena of life, which have caused so many biologists to throw up their hands in despair and ascribe to life some occult power undiscoverable by the scientific methods of the physicist and chemist.

From the leafy surface of humblest herb and mightiest tree, transpiration takes place, or the loss of water absorbed by the roots from the soil. During the day this water is usually quickly evaporated, but in the cooler air of night evaporation is reduced and some of the transpired water remains as dew upon the leaf. The pressure lifting the water from the soil to the leaf may be as great in some cases as that which would be exerted on the earth's surface by an atmosphere six to eight times the thickness of the present one, a pressure sufficient to support a column of water between two and three hundred feet high.

Various attempts have been made to explain the rise of sap in plants but as yet with no great success. The evaporation from the leaves and the absorption of water by the cells are the principal factors claimed as causing this wonderful phenomenon. Neither factor however is adequate, and the best we can do here, as in so many other cases, is to confess our ignorance, and press onward in the search for knowledge.

In this marvellous laboratory of the living body with its countless millions of little test tubes or cells, and its manifold reagents, many of which we do not know, wonderful reactions are continually taking place, whose complexity is at once the joy and the despair of the chemist, and whose study is one of the newest, most fascinating and withal most difficult fields into which chemistry has been privileged to enter. And yet marvelous as are the transformations within the body of the living being they are all without exception undoubtedly effected by physical and chemical means.

CHAPTER XII

*Experimental biology, mechanism versus vitalism continued.
Tropisms, instincts and intelligence. Hormones. Artificial fertilization.*

But can physics or chemistry explain the as yet unknown processes of nervous action; the bewildering perplexity of the instinct of bee or bird or beast, or the yet more amazing intricacies of human thought? To answer this question, as indeed to solve any of the problems of living matter aright, it is essential that we turn to the lowest rather than to the highest organisms, to those which present to us in their simplest terms, all the fundamental processes of the living thing. If the extended process or pseudopodium of an *Amœba*, one of the simplest types of living things, be touched with a finely drawn out thread of glass, the process is retracted and the direction of movement of the animal is altered thereby. If on the other hand *Amœba* comes in contact with some object, which serves as food, it reacts positively toward it, thrusting out its processes and engulfing the object. Furthermore *Amœba* can pursue its food, so that to the observer it seems as if this tiny bit of protoplasm, so small that the largest specimens appear to the naked eye as mere specks of white, were endowed with a sort of primitive intelligence. This pursuit of food has been described by Jennings as follows: "I had attempted to cut an *Amœba* in two with the tip of a glass rod. The posterior third of the *Amœba*, in the form of a wrinkled ball, remained attached to the body only by a slender cord, the remains of the ectosarc. The *Amœba* began to creep away, dragging with it this ball. I will call this *Amœba* a, while the ball will be designated b. A larger *Amœba* (c) approached, moving at right angles to the path of the first *Amœba*; its course accidentally brought it into contact with the ball b, which was dragging past its front. *Amœba* c thereupon turned, followed *Amœba* a, and began to engulf the ball b. A large cavity was formed in the anterior end of *Amœba* c, reaching back nearly or quite to its middle, and much more than sufficient to contain the ball b. *Amœba* a now turned into a new path; *Amœba* c followed (4). After the pursuit had lasted for some time the

ball b had become completely enveloped by Amœba c; the cord connecting it with Amœba a broke, and the latter went on its way (at 5) and disappears from our account. Now the anterior opening of the cavity in Amœba c became partly closed, leaving a slender canal (5). The ball b was thus



PURSUIT OF FOOD BY AMŒBA

From Jennings, "Contributions to the study of the behavior of lower organisms." Carnegie Institution, Publication No. 16. For description see text.

completely inclosed, together with a quantity of water. There was no union or adhesion of the protoplasm of b and c; on the contrary (as the sequel will show clearly) both remained quite separate, c merely inclosing b.

"Now the large Amœba c stopped, then began to move in another direction (5-6), carrying with it its meal. But

the meal, the ball b, now began to show signs of life, sent out pseudopodia, and indeed, became very active. We shall henceforth, therefore, speak of it as *Amœba b*. It began to creep out through the still open canal, sending forth its pseudopodia to the outside (7). Thereupon *Amœba c* sent forth its pseudopodia in the same direction, and after creeping in that direction several times its own length, again completely inclosed b (7-8). The latter again partly escaped (9), and was again engulfed completely (10). *Amœba c* now started again in the opposite direction (11), whereupon *Amœba b*, by a few rapid movements, escaped entirely from the posterior end of c, and was free, being completely separated from c (11-12). Thereupon c reversed its course (12), crept up to b, engulfed it completely again (13), and started away. *Amœba b* now contracted into a ball, its protoplasm clearly set off from the protoplasm of its captor, and remained quiet for a time. Apparently the drama was over. *Amœba c* went on its way for about five minutes, without any sign of life in b. In the movements of the *Amœba c* the ball b gradually became transferred to the posterior end of c, until finally there was only a thin layer between b and the outer water. Now b began to move again, sent out pseudopodia to the outside through the thin wall, and then passed bodily out into the water (14). This time *Amœba c* did not return and recapture b. The two *Amœbæ* moved in different directions and remained completely separated. The whole performance occupied, I should judge, about 12 to 15 minutes (the time was not taken till several minutes after the beginning).

"After working with simple stimuli and getting always direct simple responses, so that one begins to feel that he understands the behavior of the animal, it is somewhat bewildering to become a spectator of so striking and complicated a drama. . . . The action is remarkably like that of a higher animal. Doubtless we must assume chemical and mechanical stimuli as directives for each of the movements of c, but the analysis so obtained seems not very complete or satisfactory."¹

Injurious chemicals cause *Amœba* to withdraw from them. Similarly, if the water on one side of an *Amœba* be warmed, the animal will contract on that side, and thrusting forth its pseudopodia on the other side, move in the opposite direction. If a weak electric current be passed through the water containing *Amœba*, its behavior is similar to that under a heat stimulus. The side toward the anode or positive pole contracts, while from the opposite side pseudopodia are extended,

¹ Jennings, "Contributions to the Study of the Behavior of Lower Organisms," Carnegie Institution, Publication No. 16.

and the animal moves toward the cathode or negative pole. The behavior of *Amœba* moreover is not stereotyped, but can be adapted to suit varying conditions. If a bright light be thrown upon it, it contracts into a small inactive mass, but after a time the pseudopodia are again thrust out and activity resumed. When starved, *Amœba* becomes more active than usual, while after a heavy meal it becomes sluggish.

"All these responses are purposive in that they are adapted to the preservation of the organism. Simple as *Amœba* apparently is it manages to cope very effectively with the conditions of its existence. One might conceivably construct a machine which would run itself, gather the food needed to supply the energy used in its workings, avoid automatically contact with obstacles which would impair its running, move away from regions too hot or too cold for its efficient operation, protect itself by producing coverings in unfavorable situations, and guide itself into the most favorable regions for its maintenance; but what a wonderfully complicated mechanism it would have to be! Yet a simple, apparently almost structureless mass of jelly does all this and more. And if our mechanism had the property of repairing its own injuries and producing other pieces of mechanism like itself, its structural arrangements would be almost if not quite beyond our power to conceive. One cannot, therefore, but look with a feeling of admiration and wonder at so comparatively simple a creature as *Amœba*, which is capable of performing so much. . . .

"The behavior of *Amœba* is essentially like that of higher animals: it avoids things which are injurious; it seeks things which are beneficial and it adapts its behavior to new conditions. Life is very much the same sort of thing whether in an *Amœba* or a man."²

One must not however be too sure as to the simplicity of an *Amœba*. While to the eye of the microscopist it appears as an "almost structureless mass of jelly," nevertheless the complexity of the molecules composing this jelly is such as to defy analysis by the most skillful chemist. And even were it possible to obtain an exact analysis of the *Amœba* molecules, the number of atoms composing the latter is so great as to render possible several million combinations of these atoms, each in a different way and each possibly responsible for every new response which it makes to its surroundings.

While the behavior of *Amœba* is generally such as to benefit, rather than harm it, this is not invariably true of all organ-

² Holmes, "The Evolution of Animal Intelligence," pp. 70-71. By permission of Henry Holt and Company.

isms. Thus a one per cent solution of morphine attracts certain bacteria even though it is fatal to them. This is an unusual condition however as morphine is a substance not encountered in nature by bacteria. A similar behavior is to be found, as we shall see later, in higher animals. Nature sometimes plays the rôle of the enchantress Circe with the humblest, as well as the proudest of her creatures.

A step higher on the stage of life we come to *Paramœcium*, whose acquaintance we have already been privileged to make. Here we have an animal with definite organs of locomotion (cilia) arranged in definite (spiral) lines upon the body; an oral groove or food trough, leading to a gullet or primitive digestive tract, a definite anal spot for the discharge of undigested materials, specialized organs (contractile vacuoles) for excretion, and specialized nuclei which play a complicated rôle in the processes of metabolism and reproduction. *Paramœcium* swims in a spiral path, directed by the spirally arranged cilia, and oblique oral groove. Its active movement and peculiar form have caused many an unhappy hour to the tyro in biology. If one place a drop of weak acid in the dish of water in which *Paramœcia* are restlessly zig-zagging to and fro, they will be found after a time to have gathered in the drop; while *vice versa* a grain of salt will soon be surrounded by a zone of water free from *Paramœcia* save for the dead bodies of a few, which have ventured too near the fatal spot and failed to extricate themselves therefrom, ere death o'ertook them.

How are these results accomplished? Are *Paramœcia* attracted by, and do they swim into the drop of acid because they "like" it? And, similarly, do they avoid the salt because they "know it is bad for them"? Let us follow their maneuvers a little more closely. If a *Paramœcium* in swimming at random through the water, happens to approach a drop of acid it is not repelled by it, and hence goes into the drop if its direction of movement happens to take it there; once inside the drop however should it "attempt" to escape it cannot do so, for when it approaches the water outside the drop it is seemingly repelled by the latter, for it backs up, turns on its tail and swims away. Thus it can enter the drop but cannot leave it, and in a short time a large number of *Paramœcia* may be trapped in this manner. This behavior of *Paramœcium* has been likened by Jennings who described it, to a sort of "trial and error" behavior, similar to that of the dog who learns to open a gate by putting his paw on the latch, as a result of numberless fruitless pawings, in an attempt to escape from the yard in which he is penned up. Loeb however sees in this behavior something yet more simple

than does Jennings, ascribing the backing and turning movement of the animal on its approach to an unfavorable environment, to a reversal of the ciliary movement on the side stimulated, and to the asymmetrical shape of the body. The controversial phase of the subject is one which does not interest the general reader; the important point is that a primitive animal like *Paramecium*, lacking any specialized sense organs or nervous system, is nevertheless as sensitive to stimuli as the higher organism, with its indescribably complex organs of sense, and intricate maze of nervous paths.

Many of the unicellular organisms, both plant and animal, are exceedingly sensitive to light. This is especially well shown by the ciliate *Stentor*. This is a gourd-shaped cell, completely covered with cilia, except at the basal end or "foot" by means of which the animal occasionally attaches itself. At one end is a flattened or hollow disk surrounded by a band of strong cilia which guide the food to a depression in the disk, the mouth. Close to the outer surface of the animal are a number of delicate contractile fibrils which function as muscles, in which respect *Stentor* shows a marked advance in structure over *Paramecium*. If the water in which this ciliate is swimming be suddenly illuminated, the animal reverses its movements, turns always in the same direction (in respect to the sides of the body) and then goes ahead once more. This reaction may be repeated a number of times, with the final result that the animal, through a series of "trials and errors" is finally brought into a region of less light.

Many of the unicellular plants and animals are provided with little spots of red pigment which are sensitive to light. In these forms, which belong to the group of flagellates, or forms bearing one or more long, whip-like cilia, and many of which are on the problematical fence between plants and animals, light reactions are well marked. The reactions may be either positive or negative, vigorous or weak, and may vary with the physiological state or condition of the organism at different times; but all serve to bring it into that strength of light which the organism "likes" best, i. e., to which it is best adapted.

We are accustomed to think of unicellular organisms as expressing life in its simplest terms, but we have seen nevertheless that many of them are indeed very complex creatures, possessing organs of locomotion, digestion, excretion, contraction and even in some cases of special sense ("eye spots"). Recently Kofoed and his students working at the University of California have discovered structures in certain Protozoa which they believe represent a primitive nervous system. These are delicate fibrils which can be clearly brought out

by appropriate staining, and are connected on the one hand with the flagella or cilia and on the other with certain deeply staining granules in the body of the animal. To operate on creatures less than $1/150$ inch in length is a surgical "stunt" of no small difficulty. Yet this has been done and these delicate fibrils cut, with the resultant cessation of movement of the connected flagella. It is clear then that these fibrils represent a primitive nerve-muscle structure such as occurs in more differentiated form in some of the simpler of the many-celled animals.

The ability of higher plants to respond to stimuli is a



COMPASS PLANTS AS SEEN FROM DIFFERENT POSITIONS

From Kerner (translation by Oliver), "Natural History of Plants," Henry Holt and Company.

Print furnished by Conrad Lantern Slide Company, Chicago.

matter of common knowledge. We place a plant in our window and soon leaves and stems are bending toward the light. The compass plant is a devoted worshipper of the sun. In the dawn it turns its opening flowers eastward to greet the rising sun, while at eventide they face the west attendant on its setting. The mold *Pilobolus* grows upon horse manure. When its spores ripen they are thrown by the plant with considerable force, surrounded by the spore cases, in the direction of the light. If a little fresh horse manure be placed in a box with a small window, the filaments of the mold turn toward the window, and as the spores ripen they are thrown in their cases against the window to which they adhere. A tree is felled by a land-slide or a tornado

and some of its roots are left embedded in the ground. Soon the young flexible branches turn and grow upward opposite to the direction of gravity. Roots, on the contrary, when placed in a horizontal position, or inverted so as to point upward, will soon respond to the pull of gravity and grow downward. A seedling is suspended with its rootlets immersed in a stream of water, and soon they bend and grow against the current of the stream. Touch the leaves of the Mimosa or sensitive plant and almost immediately the paired lobes of the leaflets fold together and the leaf itself droops slightly, soon however resuming their original position if undisturbed.



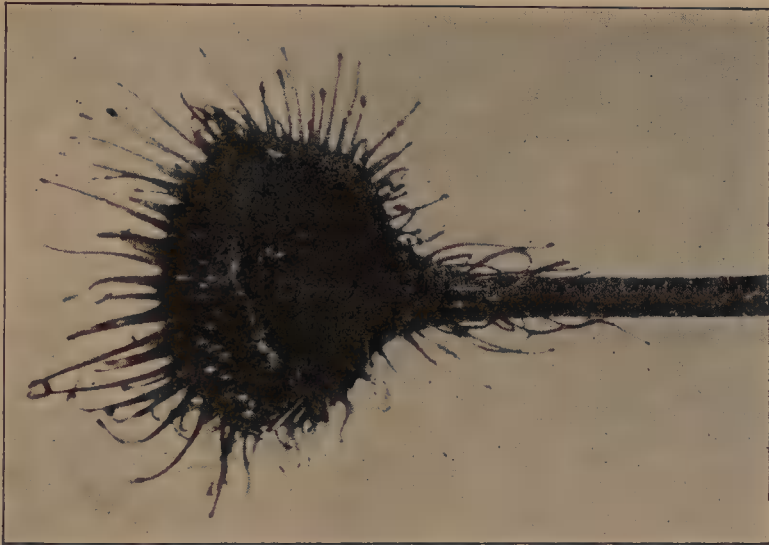
MINOSA OR SENSITIVE PLANT

From Kerner (translation by Oliver), "Natural History of Plants," Henry Holt and Company.

lobes of the leaflets fold together and the leaf itself droops slightly, soon however resuming their original position if undisturbed.

The flowers of some plants serve as insect traps. In the sun dew (*Drosera*) the leaves are covered with numerous little hairs or tentacles, which secrete a sticky fluid, which glistens in the sun like drops of dew, whence the plant derives its common name of "sun dew." Certain glands in the leaf secrete a digestive enzyme similar to the pepsin of an animal's stomach. If a drop of rain, or a grain of dust blown by

the wind, fall on the leaf, there is no movement of the tentacles or secretion of digestive fluid, but should an unlucky insect alight on a sun dew leaf attracted by the honey-like drops upon the tentacles, they bend over and figuratively speaking seize upon the intruder, while the edges of the leaf fold together, thus wrapping the leaf about its body. The digestive glands complete the tragedy and what was once an insect now becomes incorporated in a leaf. Here we find a relatively complex series of reactions co-ordinated, or working in harmony, in an organism lacking any special nervous or co-ordinating system altogether.

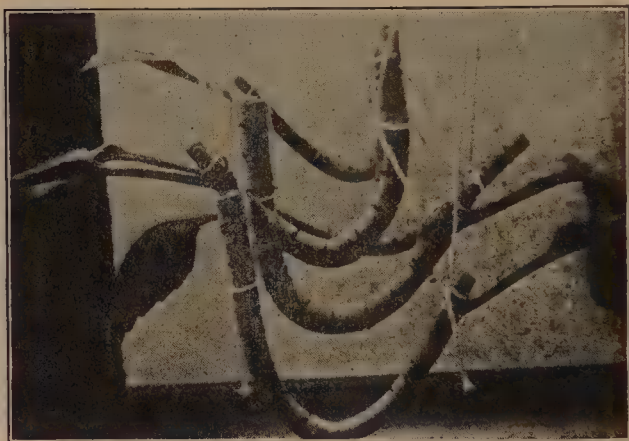


SUN DEW LEAF

Showing sticky hairs and entrapped insect. From Needham and Lloyd, "The Life of Inland Waters," Comstock Publishing Company.

Can these responses of the unicellular animals and plants be explained on a physico-chemical basis? This the leader of the mechanist school in America, Jacques Loeb, endeavors to do with his "forced movement" or "tropism theory." According to this theory every organism is in a state of physiological equilibrium or balance with respect to a median plane of symmetry, until it is subjected on one side or the other to a stimulus, such as heat, light, electricity, etc.; which stimulus induces certain physico-chemical changes, differing in degree on either side of the body, this difference forcing the organism to respond unequally on the two sides, and then perform a "forced movement" or a "tropism" (turning). While a great many of the one-celled organisms

are not strictly symmetrical they may be assumed to be so for the purposes of the theory. Thus if a *Paramœcium* be acted upon by an electric current whose direction is oblique to the long axis of its body, the cilia on the side toward the negative pole beat more vigorously than do those on the positive side, and in the opposite direction, causing the animal to turn until it is in line with the current when it swims ahead, toward the negative pole. The stem of a plant turns toward the light, or bends upward, because of a difference in amount of chemical substances on the two sides, and "this causes a difference in the velocity of chemical reactions between (the two sides)." The organism has no control over its behavior but is so to speak blown about "by every wind that blows" as helplessly as a derelict ship upon the sea.



SAGGING IN A STEM

Due to unequal growth on the two sides. From Loeb, "Forced Movements, Tropisms and Animal Conduct."

By permission of J. B. Lippincott Company.

But what proof have we that such chemical changes as Loeb assumes do occur in the organism? If we suspend a stem of a plant in a horizontal position, it soon bends downward, taking the form of a U. This bending is not due to sagging of the stem as a rope sags, but rather to unequal growth of the two sides, which can be proven by marking equal distances on upper and lower sides by lines of India ink and later measuring the amount of growth occurring between the marks. If the amount of bending in such a stem with leaves attached be compared with that in a stem lacking leaves, it will be found to be much greater in the former due to the greater amount of growth material available, and similarly there is greater bending in a stem furnished with a

complete leaf than in one with a leaf which has been partly cut away. "What has been demonstrated in this case explains probably also why the apex of many plants when put into a horizontal position grows upward, and why certain roots under similar conditions grow downward. It disposes also in all probability of the suggestion that the apex of a positively geotropic root has 'brain functions.' It is chemical mass action and not 'brain functions' which are needed to produce the changes in growth underlying geotropic curvature."³

Such an explanation however is difficult to apply to many



RELATIVE AMOUNT OF BENDING

Due to unequal growth in stems with and those without leaves. From Loeb, "Forced Movements, Tropisms and Animal Conduct."

By permission of J. B. Lippincott Company.

of the reactions of a Stentor or a Paramœcium. While the latter animal reacts to an electric current by a difference in the beat of the cilia on the two sides, and the animal is thus turned so as to swim with the current, by a process seemingly as mechanical as that of turning a boat; in other cases, as when running into a salt solution, the behavior of Paramœcium is not so simply explained, for in this circumstance it always turns in the same direction, regardless of the angle at which it meets the salt current, and even though

³Loeb, "Forced Movements, Tropisms and Animal Conduct," pp. 121-2. By permission of J. B. Lippincott Company.

this turning may bring it towards, rather than away from the unfavorable medium. Its behavior in this case is fixed in character, and not so clearly mechanical as in the former case.

A remarkable imitation of a living creature responsive to light stimuli has been invented by the American engineer John Hays Hammond, Jr. It "consists of a rectangular box about 3 feet long, $1\frac{1}{2}$ feet wide and 1 foot high mounted on three wheels, two of which are geared to a driving motor, while the third and rear wheel can be turned by electro-magnets and thus serve for guiding the machine. Two 5-inch condensing lenses on the forward end appear very much like large eyes." The operation of the machine is affected through the action of light on two selenium cells controlling electro-magnetic switches. "When one cell or both are illuminated the current is switched on to the driving motor; when one cell alone is illuminated an electro-magnet is energized and affects the turning of the rear steering wheel . . . thus bringing the shaded cell into the light. As soon and as long as both cells are equally illuminated in sufficient intensity, the machine moves in a straight line toward the light source. By throwing a switch which reverses the driving motors, the machine can be made to back away from the light in a most surprising manner.

"Upon shading or switching off the light the 'dog' can be stopped immediately, but it will resume its course behind the moving light so long as the light reaches the condensing lenses in sufficient intensity. Indeed, it is more faithful in this respect than the proverbial ass behind the bucket of oats. To the uninitiated the performance of the pseudo dog is very uncanny indeed."⁴

But what is the case with those animals with a nervous system by means of which their complex functions are made to work in orderly fashion? It would take us too far afield to attempt to trace, as Professor Parker has recently done in his admirable little book on the "Elementary Nervous System," the relation between the specialization of the latter, and the (delicacy) of their nervous responses. Suffice it to say that even in animals with a highly developed nervous system such as insects the responses in many cases at least appear to be purely mechanical. The attraction of the candle flame for the moth is proverbial, and even so highly organized an animal as a bird frequently appears to be as much a creature of circumstance as the moth, for birds often beat themselves to death in great numbers against light-houses. The purely mechanical response of an animal to stimuli is beautifully

⁴ Miessner, "Electrical Experimenter," Sept., 1915, p. 202.

illustrated by the behavior of the caterpillar of the butterfly (*Porthesia chrysorrhœa*). "This butterfly lays its eggs upon a shrub, on which the larvæ hatch in the fall and on which they hibernate, as a rule, not far from the ground. As soon as the temperature reaches a certain height, they leave the nest; under natural conditions this happens in the spring when the first leaves have begun to form on the shrub. (The larvæ can however be induced to leave the nest at any time in the winter provided the temperature is raised sufficiently.) After leaving the nest, they crawl directly upward on the shrub where they find the leaves on which they feed. If the caterpillars should move down the shrub they would starve, but this they never do, always crawling upward to where they find their food. What gives the caterpillar this never-failing certainty which saves its life and for which the human being might envy the little larva? Is it a dim recollection of experience of former generations, as Samuel Butler would have us believe? It can be shown that this instinct is merely positive heliotropism and that the light reflected from the sky guides the animals upward. The caterpillars upon waking from their winter sleep are violently positively heliotropic, and it is this heliotropism which makes the animals move upward. At the top of the branch they come in contact with a growing bud and chemical and tactile influences set the mandibles of the young caterpillar into activity. If we put these caterpillars into closed test tubes which lie with their longitudinal axes at right angles to the window they will all migrate to the window end where they will stay and starve, even if we put their favorite leaves into the test tube close behind them. These larvæ are in this condition slaves of the light.

"The few young leaves on top of a twig are quickly eaten by the caterpillar. The light which saved its life by making it creep upward where it finds its food would cause it to starve could the animal not free itself from the bondage of positive heliotropism. After having eaten it is no longer a slave of light but can and does creep downward. It can be shown that a caterpillar after having been fed loses its positive heliotropism almost completely and permanently. If we submit unfed and fed caterpillars of the same nest to the same artificial or natural source of light in two different test tubes the unfed will creep to the light and stay there until they die, while those that have eaten will pay little or no attention to the light. Their positive heliotropism has disappeared and the animal after having eaten can creep in any direction. The restlessness which accompanies the condition of starvation makes the animal leave the top of the branches and creep

downward—which is the only direction open to it—where it finds new young leaves on which it can feed. The wonderful hereditary instinct upon which the life of the animal depends is its positive heliotropism in the unfed condition and the loss of this heliotropism after having eaten. The chemical changes following the taking up of the food abolish the heliotropism just as CO_2 arouses positive heliotropism in certain *Daphnia*.’’⁵

Such an instinct as that of this caterpillar is however a relatively simple one. Can those wonderfully complex instincts of so many animals which are connected with the production and care of the young be likewise relegated to the realm of the purely mechanical? To bring the reactions of so complex an organism as a vertebrate animal with its highly developed brain, nerves and sense organs into line with those of a unicellular form or a non-nervous plant in the present state of our knowledge is a matter of great difficulty. It can be shown with a reasonable degree of probability however that even here what we call “instinct” may be purely a response to physical or chemical stimuli, modified by certain substances secreted by the body and known as “hormones” from the Greek verb *hormao* to excite.

The rôle of these substances and the bearing which they have on the “mechanistic conception of life” we shall discuss later, merely bearing in mind their existence at this point, in order to appreciate what follows.

In many fish, as for example the minnow *Fundulus*, the act of mating consists in the sexes pressing their bodies close together in such a way that as the eggs are laid by the female the sperms are pressed out by the male and are thus mixed with, and fertilize the eggs in the water. That this behavior on the part of the female at least is similar to a response to a solid object is shown by keeping the sexes separate at the spawning season, in which case the female will mate with the glass wall of the aquarium, when she happens to come in contact with it. This reaction is usually developed only in the spawning season through the influence of the hormones secreted at that time, but if the female is kept permanently isolated from the male she may perform this act at any time of year.

Loeb quotes the late Professor Whitman to the effect that male pigeons isolated from the females will attempt to mate with any solid object in their field of vision, e.g., glass bottles, and even with objects which give only the optical impression of a solid, namely their own shadow on the ground. And Craig has shown that male pigeons under these circum-

⁵Loeb, *locus citatus*, pp. 161-2.

stances will respond to a human hand. " 'The dove was kept in a room where several men were at work, and he directed his display behavior toward these men just as if they belonged to his own species. Each time I put food in his cage he became greatly excited, charging up and down the cage, bowing and cooing to me, and pecking my hand whenever it came within his cage. From that day until the day of his death, Jack continued to react in this social manner to human beings. He would bow-and-coo to me at a distance, or to my face when near the cage; but he paid greatest attention to the hand—naturally so, because it was the only part with which he daily came into direct contact. He treated the hand much as if it were a living bird. Not only were his own activities directed toward the hand as if it were a bird, but he received treatment by the hand in the same spirit. The hand could stroke him, preen his neck, even pull the feathers sharply. Jack had absolutely no fear, but ran to the hand to be stroked or teased, showing the joy that all doves show in the attentions of their companions.' When this pigeon was almost a year old it was put into a cage with a female pigeon, but although the female aroused the sexual instinct of the formerly isolated male the latter did not mate with her, but mated with the hand of his attendant when the hand was put into the cage, and this continued throughout the season. Thus the memory images acquired by the bird at an impressionable age and period perverted its sexual tropisms." ⁶

Light response is a common phenomenon among the fresh water crustaceans. During broad daylight the upper levels of a lake may be almost uninhabited by these little animals, while at greater depths they occur in large numbers. As night comes on they return to the upper regions which they have deserted by day. Loeb has shown that the behavior of some of these animals with respect to light can be totally changed by chemical treatment. Thus the fresh water *Daphnia*, *Gammarus* and other Crustacea when in a condition in which they do not respond to light can be made intensely positively heliotropic by adding some acid to the fresh water, especially weak CO_2 . If carbonated water or beer be added to water containing some of these animals they "will collect in a dense cluster on the window side of the dish." Other chemicals including alcohol give the same results. The light-minded reader may be inclined to draw an analogy between this behavior and the tendency of some individuals to enter into close communion with a lamp post in the "wee sma' hours." The alkaloids caffeine and strychnin on the other

⁶ Quoted from Loeb, *locus citatus*, pp. 168-9.

hand will make the "fresh water Crustacean *Diaptomus* intensely negatively heliotropic." Changes of temperature and osmotic pressure may bring about similar results.

The social life of the wasps, bees and ants has long been a subject for wonder and admiration. In the busy ant hive is a nest full of conundrums for the student of animal behavior, the half of which have as yet scarcely been stated. The life of these social insects is seemingly so complex that we are accustomed to think of it in terms of human life and so we have "castes" of "drones,"⁷ and "queens" and "workers." Some of these latter are "soldiers," among whom we find "scouts" and "officers," others are "nurses," still others are "harvesters" whose duty it is to fill the "granaries," while yet others are "slave-makers," whose duty it is to go out and capture "slaves." Some ants play the part of "thieves" in other ants' nests. Yet others act as "hosts" entertaining other species of ants as "guests," while some keep aphids which they milk as "cows." Some give to other ants a "shampoo," in return for which the "delighted" ant yields a drop of honey, which the shampooer licks up greedily. Ants are "brave" and fight with "ferocity," while all are "industrious" and endowed with "wisdom," Mark Twain to the contrary notwithstanding.

Can such "human" behavior be removed from the realm of poetry and relegated to the prosaic one of purely mechanical reflex?

One of the most remarkable periods in the life of the ant is the swarming time, when the winged males and "queens" perform their "nuptial" flight, rushing forth in "ecstasy" from their nest to found new colonies. After this flight the males die, the females pull off their wings and crawling into the ground either alone or accompanied by a group of workers, settle down to the humdrum duty of egg laying. Is such behavior a response to a purely physical or chemical stimulus? According to Loeb this "wedding flight" is a "heliotropic phenomenon presumably due to substances produced in the body during this period, . . . (for) at a certain time—in the writer's observation toward sunset, when the sky is illuminated at the horizon only—the whole swarm of males and females leave the nest and fly in the direction of the glow"⁸ After removing her wings the female loses her heliotropism and becomes strongly stereotropic, responding to touch stimuli, for if placed in a dark box containing folds of cloth, she is found snugly tucked away among the folds.

⁷ This term belongs of course properly to insects, and is applied secondarily to man.

⁸ Loeb, *locus citatus*, p. 158.

It is this stereotropism which causes her to seek a hiding place in the earth wherein to lay her eggs. This explanation would be very simple and satisfying did we know what it is which makes the ant at one moment responsive to light and at another to touch. "Presumably" Loeb's explanation is correct, but so long as it is founded on presumption only, it can hardly be said to be strictly scientific.

Professor Vernon Kellogg has however made some observations on the swarming of bees which prove pretty conclusively that this behavior is due to positive heliotropism in this insect. Professor Kellogg's bees were kept in a cloth jacketed hive, with a small opening at the bottom. He says, "Last spring at the normal swarming time, while standing near the jacketed hive, I heard the excited hum of a beginning swarm and noted the first issuers rushing pellmell from the entrance. Interested to see the behavior of the community in the hive during such an ecstatic condition as that of swarming, I lifted the cloth jacket, when the excited mass of bees which was pushing frantically down to the small exit in the lower corner of the hive turned with one accord about face and rushed directly upward away from the opening toward and to the top of the hive. Here the bees jammed, struggling violently. I slipped the jacket partly on; the ones covered turned down; the ones below stood undecided; I dropped the jacket completely; the mass began issuing from the exit again; I pulled off the jacket, and again the whole community of excited bees flowed—that is the word for it, so perfectly aligned and so evenly moving were all the individuals of the bee current—up to the closed top of the hive. Leaving the jacket off permanently, I prevented the issuing of the swarm until the ecstasy was passed and the usual quietly busy life of the hive was resumed. About three hours later there was a similar performance and failure to issue from the quickly unjacketed hive. On the next day another attempt to swarm was made, and after nearly an hour of struggling and moving up and down, depending on my manipulation of the black jacket, most of the bees got out of the hive's opening and the swarming came off on a weed bunch near the laboratory. That the issuance from the hive at swarming time depends upon a sudden extra-development of positive heliotropism seems obvious. The ecstasy comes and the bees crowd for the one spot of light in the normal hive, namely, the entrance opening. But when the covering jacket is lifted and the light comes strongly in from above—my hive was under a skylight—they rush toward the top, that is, toward the light. Jacket on and light shut off from above, down they rush; jacket off and light stronger from

above than below and they respond like iron filings in front of an electromagnet which has its current suddenly turned on."⁹

Our knowledge of what occurs when an impulse is sent over a nerve is very vague, but we have certain knowledge that physical and chemical changes take place in nerve cells and fibers coincident with such impulses, so that we are justified in believing that these impulses are physico-chemical phenomena. At the University of Chicago a young Japanese, Tashiro, a few years ago designed a very delicate little instrument which he calls the biometer, or measurer of life. By means of this instrument he is able to detect traces of carbon dioxide as small as one thirty-millionth of an ounce. If a living nerve fiber be placed in the biometer and stimulated by an electrical current it is found to give off carbon dioxide as the other tissues of the body when they are made to work. There is combustion of living matter then when an impulse travels along a nerve. In the body of a nerve cell are certain peculiarly staining masses known as the Nissl bodies. When a nerve cell is stimulated successively several times these bodies disappear. Some chemical substance has been consumed in the activity of the cell. Nervous activity develops electrical currents which can be measured on a galvanometer, and with very delicate instruments electrical currents can even be detected in the resting nerve. The impulse is not instantaneous but requires measurable time for its transmission. The intensity of the impulses can be measured, as one measures the intensity of sound, light, electrical energy or other physical energy. Nerve action can be checked by means of suitable chemicals (anesthetics), while on the other hand certain substances, such as sodium, increase it. Anesthetics may produce similar effects in non-nervous tissues and even in non-living matter. Thus Osterhout has shown that small quantities of anesthetics in the sea water decrease the electrical conductivity of seaweed, and several observers have shown that they check the passage of substances through cell membranes. If charcoal made from blood be mixed with a solution of oxalic acid containing free oxygen, the acid is changed to carbon dioxide and water, the charcoal acting as a catalyzer. This catalytic power of the charcoal can be retarded by certain substances (i.e., carbon bisulphide) which act as anesthetics and which can also check the action of finely divided platinum in the separation (catalysis) of hydrogen peroxide to water and oxygen. If therefore anesthetics produce effects in non-nervous and even in non-living substances similar to

⁹ Kellogg, V, "Some Insect Reflexes," "Science," XVIII, pp. 693-4.

those which they produce in nerves, we have good reason to believe that their action on the latter is similar to that on the former or that the prevention of nervous action, and therefore that action itself is fundamentally a physico-chemical one.

But can physics and chemistry explain all the complicated instincts of the insect, bird and mammal, or the as yet unsolved riddle of human thought? Frankly we must admit that at present we do not know. According to Loeb these are merely "tropistic reactions" modified by "memory images," which have an "orienting effect" upon the organism, and which he attempts to explain by an illustration from the behavior of the solitary wasp *Ammophila*, which digs a hole in the ground in which to lay its eggs.

Ammophila, a solitary wasp, makes a small hole in the ground and then goes out to hunt for a caterpillar, which, when found, it paralyzes by one or several stings. The wasp carries the caterpillar back to the nest, puts it into the hole, and covers the latter with sand. Before this is done, it deposits its eggs on the caterpillar which serves the young larva as food.

"An *Ammophila* had made a hole in a flower bed and left the flower bed flying. A little later I saw an *Ammophila* running on the sidewalk of the street in front of the garden, dragging a caterpillar which it held in its mouth. The weight of the caterpillar prevented the wasp from flying. The garden was higher than the sidewalk and separated from it by a stone wall. The wasp repeatedly made an attempt to climb upon the stone wall, but kept falling down. Suspecting that it might have a hole prepared in the garden, I was curious to see whether and how it would find the hole. It followed the wall until it reached the neighboring yard, which had no wall. It now left the street and crawled into this yard, dragging the caterpillar along. Then crawling through the fence which separated the two yards, it dropped the caterpillar near the foot of a tree, and flew away. After a short zigzag flight it alighted on a flower bed in which I noticed two small holes. It soon left the bed and flew back to the tree, not in a straight line but in three stages, stopping twice on its way. At the third stop it landed at the place where the caterpillar lay. The caterpillar was then dragged to the hole, pulled into it, and the hole was covered with tiny stones in the usual way."¹⁰

Aside from the fact that we have no explanation of the physico-chemical processes underlying these "memory images," it is difficult to apply the theory to many of the

■ Loeb, *locus citatus*, p. 170.

common reactions of higher animals. Can "memory images" teach a bird how to build its nest for the first time, or guide the bees in the construction of their wonderful combs? Can their "orienting effect" explain the return to its nest of the terns which Watson carried from the Florida Keys to Cape Hatteras, a distance of 150 miles from their home, into a region never before visited by the birds? Possibly, although it requires a mighty effort of the imagination to unite cause and effect in this instance. But it is easy to find flaws in any theory which boldly ventures into the comparatively uncharted sea of animal reactions, and endeavors there to lay down a course which we may in safety follow; so let us comfort ourselves with believing that "free will" has no place in science, but is merely an expression of the "verbalists," and that we simply "go where our legs carry us," a theory which has at least the advantage of enabling us to smile complacently, while ancient preachers hurl their anathemas at the damned.

We have spoken above of certain substances secreted by the animal body and known as hormones, which exercise a determining influence in animal behavior. What are these substances, how are they formed and what rôle do they play in animal physiology?

The recognition of the value of various organs in curing disease goes back to the days of Hippocrates, the "father of medicine," and since his time many such remedies have been proposed. Thus the liver of the pigeon or the wolf were used in cases of disease of the liver, the rabbit's brain was given for tremors, and the lung of the fox for difficulty in breathing. The testicles of the donkey or the stag were recommended by Pliny for the renovation of the debauchee, and even today (castoreum) a preparation obtained from the preputial glands of the beaver is sometimes employed for colic, hysteria and other disorders. In more recent days the French physiologist Claude Bernard advanced the view that all tissues give some secretion to the blood, which is of use in the nutrition of the body, and while our knowledge of these substances is as yet very fragmentary, their great importance in the life of the animal and their usefulness in the treatment of various disorders, are widely recognized. It is known for example that diabetes, which is marked by the presence of sugar in the urine, is not a kidney disorder, but is due to improper action of the pancreas, as a result of which a specific secretion, passed by the latter into the blood stream and functioning in sugar metabolism, is absent or reduced in amount.

Imperfect development of the thyroid gland leads to the

condition of under development both mental and physical, which is known as cretinism from the French word cretin. Feeding the extract of the thyroid gland of a sheep, or the gland itself, either raw or cooked, results in great increase in growth and development of both mind and body in such cases. The use of adrenalin (extract of the adrenal gland of some animal) is a common practise in certain diseases and injuries as, for example, asthma, in which injections of the drug relax the bronchial muscles, and greatly relieve the sufferer. Attached to the lower, central part of the brain is a small gland, the pituitary body, which some enthusiastic theorists have fancied to be the seat of the soul. If this gland be partly removed from a young puppy it ceases to grow except for the accumulation of fat. It keeps its puppy hair and milk teeth, while the development of the genital organs, and of the intelligence is much retarded.

After partial digestion in the stomach, the food is further digested in the upper end of the small intestine. The digestive juices come in part from the liver and wall of the intestine itself, and in part from the pancreas. When the partly digested and acid food passes from the stomach into the intestine, it causes the pancreatic juice to flow as automatically as the movement of the piston in a gasoline engine causes the intake of gasoline from the supply tank. The pancreas is activated by the acid food in the intestine. It was formerly supposed that this activation was effected by reflex nerve action, but we now know of an entirely different mechanism for this function. If an acid extract of the lining of the intestine be injected into the blood it causes the pancreas to secrete its juice as surely as does the presence of acid food in the intestine; while similar extracts of other organs have no such effect. Here there is clear evidence of an internal secretion formed by the intestine, which reaching the pancreas via the blood causes the latter to act. A beautiful example of the chemical control of bodily functions.

On the run of any through train between the terminals of a great trunk line there is a change of engines about once every 200 or 250 miles. Neither engine nor crew can give as effective service if operating for greater distances. The non-living, as well as the living machine needs rest after a certain period of work.

Recently the well-known surgeon, Crile of Cleveland, has advanced an interesting theory which he calls the "kinetic drive" to explain the running down of the human mechanism. In the "kinetic drive" of modern life, when the human machine is being driven at top speed, stored or poten-

tial energy is converted into active or kinetic energy, and the tissues of the body suffer corresponding loss. According to Crile certain parts of the brain furnish the nervous energy, which is probably identical with electrical energy, and which controls muscular, and other activity. The adrenal glands furnish adrenalin, which in some way determines the oxidation processes in the brain to which the nervous energy is due. The thyroid gland, which Crile calls the "pace-maker" of the body, furnishes iodine to the tissues and ren-



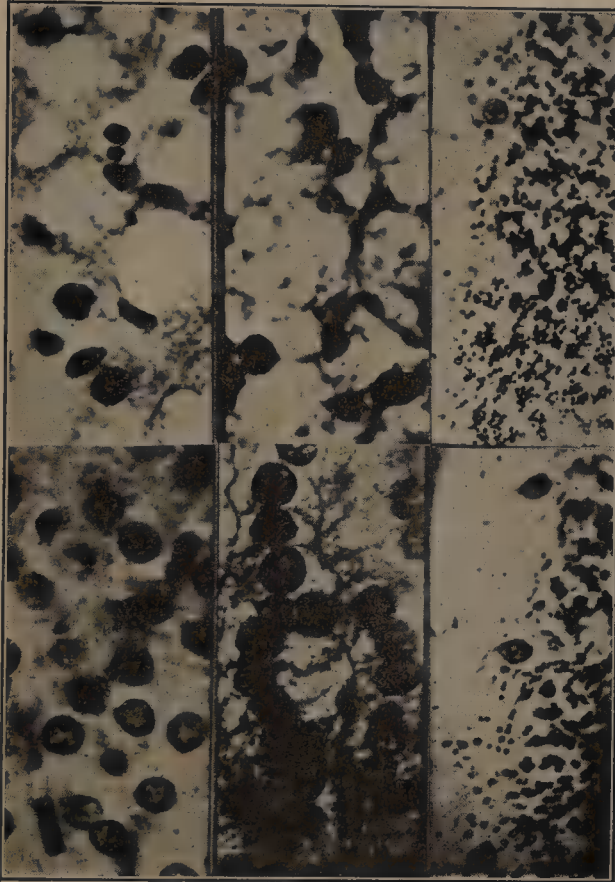
EFFECT OF THE KINETIC DRIVE

Photograph of a soldier under extreme mental and physical stress. From Crile, "The Kinetic Drive." "Journal of the American Medical Association," Vol. LXV.

ders them more permeable to the nervous impulses. In the conversion of energy in the body certain acid waste products are formed which are eliminated by the liver, kidneys and lungs. The blood is thus kept alkaline, in which condition only is the carriage of oxygen to the tissues possible.

If the production of adrenalin, the secretion of the adrenal glands, be prevented, either by removal of these glands, by cutting the nerves which supply them or by narcotizing the latter with morphin, activity is reduced. On the other hand administration of adrenalin produces results similar to

those of exertion, emotion, injury, etc., all of which lead to increase of energy change, while its continual administration leads to symptoms of exhaustion such as disorders of heart or kidney. Excessive doses of iodine also "cause



EFFECT OF THE KINETIC DRIVE ON THE TISSUES OF THE BODY.

Above, left to right, section of normal cerebellum, adrenal and liver; below, sections of the same organs of a soldier who "had suffered from hunger, thirst and loss of sleep, had made the extraordinary forced march of 180 miles from Mons to the Marne; in the midst of the great battle was wounded by the explosion of a shell; lay for hours awaiting help and died from exhaustion soon after reaching the ambulance." From Crile, "The Kinetic Drive," "Journal of the American Medical Association," Vol. LXV.

all the phenomena of emotion and exertion, and inversely . . . emotion, infection, exertion, etc., cause changes in the iodine content of the thyroid."

The results of the kinetic drive are evident in changes of the tissues. The brain of a man who has died from exhaus-

tion gives a very different picture from that of a man killed accidentally, certain of the cells having almost disappeared in the former. The injection of poison (i.e. diphtheria toxin) into a dog will produce similar changes in the brain, but these changes can be in large measure prevented by the injection of morphin at the same time as the toxin, the former checking the nervous action induced by the latter.

"Never before has there been such an opportunity for studying the behavior of the human mechanism under the strongest physical and psychic stress as in warring Europe today. There observations of the injured, of soldiers in the field, of prisoners and of refugees gave me an unparalleled opportunity for studying the human kinetic drive on a vast scale. The illustration shows the gross effect of the combination of extreme emotion and exertion as they are manifested in the faces and bearing of Belgium refugees and of wounded soldiers.

"Turning now from the individual acutely driven by injury, by infection, by emotion, let us consider the individual chronically driven by the stimuli of want, ambition, anger, jealousy or grief, by infection, by pain and by autointoxication. In the acute kinetic drive the individual is endangered by death from exhaustion or from acid intoxication, whereas in the chronic drive, the danger is that one or another of the overdriven organs or tissues may be permanently injured.

"The common chronic drives are mental and physical overwork, chronic infections, excessive diet and pregnancy, the emotions of fear, hate, jealousy, shame and despair, and foreign proteins, as in intestinal stasis. These conditions present every-day problems and demand but little discussion. Since the lesions of these various driving causes are the same, however; since infection, emotion and overwork produce identical end-effects; since usually two or more of these operate simultaneously, and since the emotional states are most amenable to control, it becomes obvious why these conditions have often been controlled by means which have apparently no direct therapeutic value, such as faith in the physician, travel, diversion, prayer, healing springs, philosophy and Christian Science. Again and again, in the domain of regular medicine as in the domain of irregular medicine, the exclusion of worry has relieved the drive sufficiently to allow the body processes to overcome the primary disease. But the reverse is true also—innumerable men, under the strain of a chronic drive, are pushed beyond the narrow limits of safety by the added drive of grief, worry or shame. Is it not possible that when it is understood that the various kinetic stimuli have

interchangeable physical values, the game of health will be more skilfully played?"¹¹

Not only may poisons, emotion and fatigue induce the kinetic drive, but surgical shock, while the patient is anesthetized, coupled with the terror of the knife before the operation, are also powerfully inducing causes. While the patient may be entirely unconscious during the operation, there is nevertheless a great drain upon the nervous system induced by the action of the knife. To overcome these as much as possible Doctor Crile takes every pains to render the patient mentally at ease before the operation and block the kinetic drive by the use of morphin and by local anesthesia. Doctor Crile's theory and this operative method are generally known as that of "anoci-association," or the prevention of the exhaustion of nervous energy through operative shock. Experiments upon which it is based have led him to many other discoveries in the field of operative surgery, which have rendered his name famous, but this brief sketch must suffice as an illustration of the automatic and mechanical operation of the human machine.

One of the most striking examples of the rôle of hormones or internal secretions is the action of the sex glands in controlling both body form and mental activity. The physical and mental changes occurring in both boys and girls at the time of puberty are too well known to require even passing mention here, while the dependence on the proper functioning of the sex glands of the secondary sexual characters, such as the horns of the deer, the comb and feathering of the cock, the size of the stallion, and innumerable others, is equally familiar to everyone. Horses and cattle are castrated to render them docile and serviceable as draft animals, and the cock is castrated in order that he may take on more flesh and become a welcome member of our dinner parties. A curious case is that of the race of poultry known as sebrights where the male goes masquerading in female attire, while the female wears the habit of the male. Castration of either sex of these chickens results curiously enough in their adoption of their proper garb, either male or female.

We are accustomed to think of the control of mind over matter and to regard the processes of thought as transcending the bounds of the purely material universe, and yet where could we have a more beautiful example of the chemical (and therefore purely material) control of living processes, mental as well as physical, than in the case of the hormones or internal secretions of the animal body?

¹¹ Crile, "Journal of the American Medical Association," LXV, p. 2132.



SEBRIGHT POULTRY

Photographs of a normal sebright cock (above), which has the plumage of the hen, and castrated cock (below), which has male feathers. After Morgan, "Physical Basis of Heredity."

Courtesy of Professor Morgan and the J. B. Lippincott Company.

Of all the features characteristic of living matter, none is more so than reproduction. Attempts have, it is true, been made to compare the growth of many crystals of salt in a concentrating solution with this miracle of life, but such attempts sound like a mere play upon words. There is nothing in the inorganic world in any way comparable to this wonderful phenomenon. Here then, if anywhere in the world of life, we should find evidence of some force higher than the physical forces, did any such exist. But what do we find? We have seen in a previous chapter that the method of reproduction (bi-sexual or parthenogenetic) can be altered by external means; furthermore in *Hydra* it can similarly be changed from asexual (budding) to sexual. In some plants likewise the kind of reproduction may be determined by external factors. But beyond the mere shifting of the mode of reproduction by physical or chemical stimuli, it has been found that the process of sexual reproduction itself is a physico-chemical one and can be accomplished by artificial means. In the first place the attraction between the sex cells is in some cases, though apparently not in all, a chemical one. If a capillary glass tube containing a weak solution of malic acid (the acid found in apples and other fruits) be placed in water containing the sperms of ferns and mosses, the latter are attracted by the acid, and will enter the tube in great numbers. The action here however may be similar to that described above of "trapping" *Paramœcium* in a drop of acid. With the spermatozoa of the sea urchin however such chemical attraction appears not to exist. The union of egg and sperm in cases where chemical attraction cannot be proven appears to be due to chance. It is a well-known fact that it is very difficult to cross different species of animals, this difference indeed being made the basis for a physiological definition of species, those animals which breed together and produce fertile offspring being grouped as one species; and those which do not interbreed, or do not at least produce fertile offspring being classed as distinct. In lower animals union of egg and sperm of different species may be prevented by physical differences such as size, or chemical differences may prevent the development of an egg into which by chance a foreign sperm has entered. In some cases it is possible to fertilize the egg of species A with the sperm of B, but the reciprocal cross is impossible. Among higher types there appears to exist a mutual repugnance to union, which effectually bars intermingling. Yet even here occasional instances of crossing and the production of fertile offspring are known, in crosses of hares and rabbits, various species of fish, etc. Crosses between members of widely distinct groups

of animals are practically unknown in nature, and yet Loeb has succeeded in cross fertilizing the sea urchin's egg with the sperm of several species of starfish and one of the brittle stars, by simply adding a little sodium hydroxide or carbonate to the sea water containing the eggs.

The entrance of the sperm into the egg induces changes in the latter which can likewise be induced by chemical means. When the sperm of a sea urchin strikes the egg the two adhere to each other, due probably to a sticky secretion of the latter. A few moments later the very delicate membrane surrounding the egg is pushed off from the surface and considerably thickened, due probably to absorption of water. The cause of this membrane formation (or better, membrane extrusion) is the liquefying of the surface of the egg just beneath the membrane and its consequent absorption of water. Subsequent to this membrane formation the sperm head or nucleus penetrates still farther into the egg leaving the tail adherent to the egg membrane, while the egg nucleus advances to meet it, the two fuse and fertilization is accomplished, to be followed shortly by the division of the egg into first two, then four, eight, sixteen cells, and so on. Many workers have succeeded in imitating the processes of fertilization and causing the eggs of a large number of species of animals to develop parthenogenetically by various methods of treatment. In the case of the sea urchin Loeb first treats the egg with some chemical (i.e., butyric or other monobasic fatty acid) which induces membrane formation, and then follows this treatment by placing the egg in sea water containing a little more salt than usual, or into normal sea water lacking oxygen. The two procedures are essential to development, for if the first alone be employed the egg disintegrates after extruding its membrane, without further development. A similar result sometimes occurs when a sea urchin egg is fertilized by starfish sperm. Here the entrance of the sperm is very slow, some ten to fifty minutes compared with about a minute in the case of sperm of the same species. In the former case, owing no doubt to the slow penetration of the sperm, the latter does not always enter the egg, but remains attached to the extruded membrane. It seems therefore that the sperm secretes two distinct substances, one of which causes liquefaction of the surface layer of the egg, with consequent absorption of water and extrusion of the membrane, while the other causes the initial development (division of the egg) to ensue. The action of this second substance is not yet clearly understood but apart from the experiments in artificial parthenogenesis and the occasional cessation of development after membrane forma-

tion in the cross fertilization experiments just mentioned, there are numerous other evidences of the action of two substances in fertilization. If, for example, the sea urchin egg be treated with the sperm of sharks or roosters, or with the blood or extracts of the organs of some invertebrates, or the blood sera of cattle, sheep, pigs or rabbits, membrane extrusion is induced but development soon ceases, unless the egg be transferred to a strengthened solution of sea water, in which development progresses for a time at least. The initial effect here (membrane extrusion) is the same as that obtained by the use of a fatty acid in artificial parthenogenesis, the second effect (division of the egg) being obtained in the same manner in both cases. There are many other ways in which eggs can be made to develop without fertilization: brushing the surface of the egg with a fine brush, plunging it for a few moments into concentrated sulphuric acid and pricking the egg membrane have all been successfully employed. The egg of even so highly organized an animal as the frog has been made to develop simply by pricking the egg membrane, and the resulting embryo reared to the adult state.

What more striking evidence could be asked of the physico-chemical nature of life, than the development of a new being by these means?

Far distant though we be from a solution of the "riddle of life" our only present hope of ultimate success is to proceed from the known to the unknown, working on the hypothesis that nature is a unity and not a duality, and that the same fundamental laws control organic and inorganic worlds alike.

CHAPTER XIII

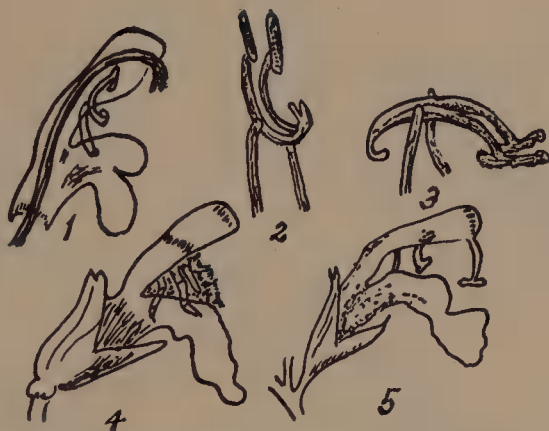
Color in Nature. Colors of flowers and the inter-relation of flowers and insects. Colors of animals and their physico-chemical causes. The theories of protective coloration, warning and alluring colors, mimicry and recognition marks.

But few American naturalists have entered the broad and fascinating field of Nature's colors. The subject was one of intense interest to Darwin and his co-workers, Wallace, Bates and Fritz Müller, and has been largely developed by the recent Darwinians in Germany and England. A few Americans however have made valuable contributions to the subject which we shall consider in this chapter.

What is the cause and what the function of the bewildering array of colors which we find on every hand? Are they useful to their possessors, and hence preserved through selection, or are they simply an expression of a reckless generosity of Nature, who lavishes her gifts with wild prodigality upon her creatures, regardless of whether they are benefited thereby or no? In the case of chlorophyl, the green coloring matter of leaves, and hæmoglobin to which the red color of the blood is due, we know of course the physiological value, but most colors (those of flowers and insects for example) are of uncertain value, although many very pretty theories have been invented to account for them.

The colors of flowers are formed as by-products of their metabolism. Their function is possibly to attract insects and thus aid in their fertilization. We have all of us been familiar since childhood with the "busy little bee," and how it "employs each shining hour" has ever been set before us for our edification and emulation; but the beautiful manner in which Nature has fashioned her children, both bee and flower, for the accomplishment of her "purpose" is not so familiar to us all. To attempt to recount here even in small measure the life of the bee would carry us too far aside from our main theme, and would moreover be a thankless task for one following in the footsteps of a Maeterlinck or a Fabre. We may however pause for a moment to consider the relation between a single sort of bee and a single kind of flower, in order to gain some notion of the wonderful co-adaptation

existing between them. The body of a worker honey bee, which gathers the honey and the pollen for the hive, and performs all the other "chores" of the bee community, such as those of nurse maid, house cleaner, butler, architect, policeman, and even executioner and undertaker, is clothed with numerous branched hairs, to which the pollen adheres as the bee goes crawling about in the cups of the flowers which it visits. On one of the joints of the middle leg of the bee is a groove, overhung by rows of stiff bristles, forming the "pollen basket," while another joint of the same leg carries several rows of bristles or "pollen combs," by means of which the pollen is combed out of the hairs and transferred to the pollen basket where it sticks in the form of a large ball. The "basket" enables the bee to carry more



RELATION OF BEE AND FLOWER, A SALVIA.

1, flower parts in usual position; 2, anthers erect; 3, anthers tipped down; 4, bee entering flower; 5, flower with extruded style. From Kellogg, after Lubbock.

pollen to its hive than it could if it depended solely on the hairs for this purpose. A part of the bee's esophagus is enlarged to form a "honey sac" in which is stored the nectar which it sucks from the flowers, and which in the hive is evaporated to form the honey.

As the bee goes buzzing about from flower to flower, in search of nectar, some of the pollen from one flower is transferred to another, and fertilization is thus effected. The manifold modifications of various types of flowers to ensure transference of pollen by insects, and to admit only those species which will pay for their supply of honey by transferring pollen, the insect Bolsheviki and I.W.W.'s, which would appropriate the honey but carry no pollen in return,

being debarred from entrance, are so numerous and wonderful as to need for their description a volume in itself. We must content ourselves with a single instance.

In one of the *Salvias* (*S. officinalis*) the stamens ripen before the pistil, so that the flower cannot fertilize itself with its own pollen.¹ The corolla of the flower consists of two lobes or lips, an upper and a lower, the former enclosing the style and stamens and the lower serving as a landing stage for insect visitors. Before the ovary ripens the style is withdrawn within the upper lobe of the corolla, as shown at 1 in the preceding figure; after ripening it hangs down over the lower lip, 5. In the former position it is not ordinarily touched by an insect entering the flower, while in the latter it obviously must be. The functional stamens are two in number, placed close together at the base of the hood. Each stamen bears two anthers, separated by a long connective, which stands upright beneath the hood. The lower pair of anthers contain little or no pollen, while the upper pair are full of it. If a bee alights on the lower lip and attempts to make his way into the flower tube, where the nectar is hidden, his head must first of all encounter the lower pair of partly developed anthers. As these are pushed before him in his effort to enter, the upper pair are swung down upon their hinge, striking the bee's back and depositing thereon their load of pollen. Thus the bee, visiting this *Salvia*, is either besprinkled with pollen to be carried to another flower, or deposits some of its pollen upon the hanging styles ready to receive it, according to the stage of development of ovaries and stamens.

The question of the part played by flower color in these transactions is very perplexing, and calls for much more investigation. Some authors maintain, while others deny, the power of insects to distinguish color, and more especially to discriminate between color patterns in flowers. An insect's power of sight is probably very limited, so that its distinction of the form, and possibly also of the color of flowers at any considerable distance is doubtful. There are however some very clear experiments showing ability on the part of insects to distinguish color, but the whole question is still very doubtful.

Animal colors fall into two classes—the chemical and the physical, or a combination of the two. The chemical colors are due to pigments diffused mainly through either the sur-

¹In some species of plants the flowers are on the contrary so constructed as to insure self-fertilization. The whole question of the influence of inbreeding upon virility in both plants and animals is very uncertain at the present time. See page 85.

face cells, the cuticula or elsewhere, or else lodged in special cells known as chromatophores, the absorption of certain rays of light by these pigments, and the reflection of their complementary rays causing the various colors. Pigments develop through the action of an oxidizing ferment upon a color-forming substance or chromogen, and many different pigments may be merely different stages in the modification of a single chromogen. Thus the brown and black pigments of animals pass through yellow, orange and red stages, before attaining their final color.

The influence of external factors in producing more or less permanent color changes in animals has been discussed in a previous chapter, dealing with the influence of the environment upon the development of the individual. Temporary changes in the hue or color of animals may result in response to external stimuli. The chameleon is the classical example of this. Temperature and light appear to be the controlling stimuli although their effects differ in different species. Fear may affect the color of an animal. Thus it is possible to cause a frog to "turn pale with fear" by continually disturbing it with a stick or otherwise. The color changes in these cases are due to changes in the distribution of the granules of pigment in the chromatophores; when the pigment is distributed throughout the cell the color is darker, when concentrated around the nucleus the reverse is true.

One of the most remarkable cases of color adaptation known is that of the flatfish. Symmetrical both in form and color in its early stages this fish soon turns on its side and thereafter lies on the bottom of the sea. Accompanying this change in life the eyes, fins and mouth shift to the upper side of the body, and the lower side loses its color. But, as the English naturalist Cunningham has shown, the color will return to the lower side in fish kept in an aquarium which is lighted from below. Living on the bottom the flatfish finds itself from time to time on differently colored backgrounds, now on white and now on dark sand, and again on gravel of various shades and patterns. In an extensive series of experiments Sumner has shown that this species adjusts its color to match that of its background with wonderful accuracy; and that further this change is affected in some unknown way through the nervous system in response to sight, for if the eye be removed the power of adjustment is lost with it.

The physical colors of animals are due to the form of the body surface, causing refraction and the formation of "metallic" coloring, or interference of the reflected light rays, thus producing the wonderful iridescence characteristic of

many beetles and birds. Metallic colors and iridescence are generally super-imposed on pigment color producing a compound effect, white being the only purely physical color that we know in animals.

The functions of animal colors are doubtless manifold, but concerning them our knowledge is unfortunately very fragmentary. Omitting those internal pigments such as hæmoglobin, bile pigments and the like, which are intimately related to the physiology of the animal, and pigments derived from the animal's food, such as the green or yellow color of some caterpillars fed on green leaves or yellow flowers re-



ONE OF THE FLATFISHES

Animals having remarkable powers of adjusting their appearance to the bottom on which they lie. The same fish photographed on different backgrounds.

Courtesy of Dr. F. B. Sumner.

spectively; and considering surface color only, we are struck with the apparent lack of any physiological use of such color. One might expect arctic animals to be black so as to absorb the maximum of heat energy from the sun, and tropical animals to be white, thereby reflecting the sun's rays and avoiding absorption of heat; but the reverse is true of the former, while the latter are widely variable in color.

How then may the multitude of colors and markings in animals be explained? The follower of Darwin bases his answer on the efficacy of selection in preserving those forms

which are best adapted to their environment. With selection then as a framework a number of theories have been advanced in explanation of animal colors.

The first of these is that of protective color which may be



PROTECTIVE FORM AND COLOR IN ANIMALS

- A. Woodcock on her nest. From a photograph by Dugmore.
- B. Night hawk on a log.
- C. Toad on ground.
- D. Tree toad on bark.
- E. Tree lizards on oak bark.
- F. Caterpillar on twig.

From Metcalf, "Organic Evolution."

By permission of the Macmillan Company.

either general or specific. "Camouflage" is not a new art to animals, and man in adapting it to his own use has been merely following the advice of Solomon, and learning wisdom from the humbler creatures of field and forest. The existence of a close resemblance between many animals and



A LEAF INSECT

Courtesy of the U. S. Bureau of Entomology.

their background must be evident to anyone who has ever wandered afield in search of Nature's creatures. Whoever is skeptical as to this statement may readily verify it by a



GROUP OF WALKING STICK INSECTS

Courtesy of the U. S. Bureau of Entomology.

search for the "peeper," the first of the frog orchestra to give melody to our marshes in the spring. Or let him look for a grasshopper after it has jumped, for a night hawk on

the ground or a tree toad on bark. But yet more striking examples of protective color are furnished by those animals which closely resemble some particular object. There are certain caterpillars commonly known as "measuring worms" which progress by a series of looping movements, first attaching themselves by the fore feet and then drawing up the hind feet, thus forming a loop of the body between. Sometimes these attach themselves to a twig by the hind feet, extending the body in the air, when they almost exactly imitate a dead twig. In our Southern States is found the



DEAD LEAF BUTTERFLY

Left, with wings folded; right, expanded. Original photograph from a preparation by Kny-Scheerer Company.

"walking stick" insect, a creature with slim body and long legs, which when resting upon a dead branch merges with its twigs so closely as to appear like part of them. One species of moth, resting on the edge of a leaf, is almost indistinguishable from the dry, curled up edge of that same leaf; while another resembles a bit of bird's dung so closely as to deceive any but the most careful observer.

But the most beautiful example of animal "camouflage" is furnished by the "dead leaf" butterfly, *Kallima*, of the East Indian jungle. When in flight this butterfly is a beautiful creature with blue and orange wings; but when at rest, with the wings folded together above the body, it imitates a dead leaf so closely, even to the minute details of

mid-rib and veins, as to deceive, at a little distance, the closest observer. When in flight the butterfly is a striking object, but let it alight, and lo, it vanishes from sight as suddenly and completely as though the earth had swallowed it up.

But some animals, who have no enemies, unless it be man, who has appeared on the scene of action only recently, in terms of biological time, closely resemble their surroundings. Perhaps the most notable example of this is the polar bear, who lives among the snows and ice fields of the Arctic. His color is readily explained, according to the Darwinians, on the assumption of an aggressive resemblance. If the seal, upon which the bear preys, cannot see the latter as he ap-



IMITATION OF AN ORCHID (LEFT) BY A MANTIS (RIGHT)

Courtesy of Thomas Y. Crowell Publishing Company.

proaches he will be more readily caught, so that in this way a resemblance to his surroundings is of advantage to the bear.

Closely allied to this theory is that of alluring resemblance, according to which certain animals play the part of a "wolf in sheep's clothing." One of the worst of these hypocrites is the Indian mantis, which so closely resembles an orchid blossom as (supposedly) to attract unwary insects, who, alighting on it in search of honey, thereby come to an untimely end.

But by no means all animals are thus protectively colored. Some on the contrary are so conspicuous that it seems as if Nature had intentionally singled them out for objects of remark. The monarch butterfly in his brilliant livery of black and orange, the skunk in striking garb of black and



THE SKUNK

An example of "warning color" among mammals.
Courtesy of the Conrad Lantern Slide Company, Chicago.



PORKFISH

One of the many strikingly marked and colored fish of the tropics, whose colors and markings have been supposed to have warning significance.

Courtesy of Professor W. H. Longley.



MIMICRY OF THE MONARCH (LEFT) BY THE VICEROY BUTTERFLY (RIGHT)

Photos from water color drawings by Mrs. Edith Ricker. From Bulletin University of Montana, Biological Series No. 5.

white, and the coral reef fish of the tropics with their "coats of many colors," all seem designed to attract, rather than detract attention. To explain such facts as these a new theory was necessary, and so Wallace suggested that these conspicuous colors were developed as a danger signal to the enemies of their possessors, warning them of an unpleasant taste, or odor, or other disagreeable feature pertaining to the lat-

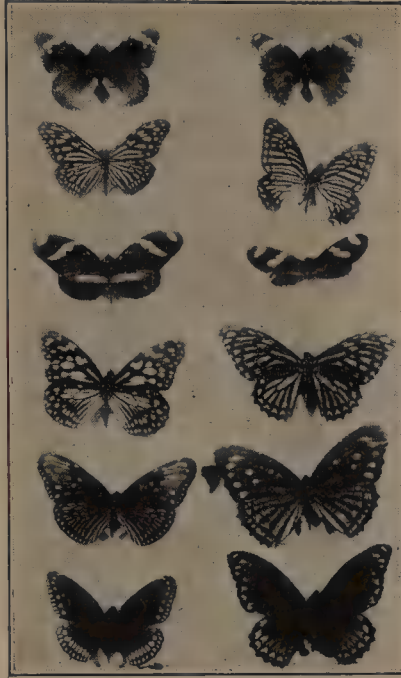


BUMBLEBEE (LEFT) MIMICKED BY FLY (RIGHT)

Photos from water color drawings by Mrs. Edith Ricker. From Bulletin University of Montana, Biological Series No. 5.

ter. Thus, according to the theory, the black and white stripes of the skunk serve as a pictorial warning to his enemies to stop, look and sniff before crossing his track. This theory is known as that of warning color.

One of the most remarkable of color phenomena in animals is that known as mimicry. In some cases there occurs a resemblance so close as to amount almost to identity between two species belonging to totally distinct genera, fam-



MIMICRY IN BUTTERFLIES

At the left a series of stinking or unpalatable forms, the "models"; with a series of imitators or "mimics" at the right. From a preparation by Kny-Scheerer Company.



MIMICRY OF LEAF-CUTTING ANT BY A TREE-HOPPER

From Romanes, "Darwin and after Darwin."

By permission of the Open Court Publishing Company.

ilies, or even orders of animals. The "monarch" butterfly already mentioned is imitated by the "viceroy," a species belonging to another genus. In South and Central America occur groups of inedible butterflies, the *Heliconidæ* and *Danaidæ*, which are imitated by various species of edible butterflies and moths, mostly the *Pieridæ*, the chief representative of which in the United States is the common cabbage butterfly. Many a fly has adopted the habit of a wasp or a bee, and the resemblance is so perfect that only the closest scrutiny reveals the deception. But perhaps the most curious of Nature's masquerades is that played by an ant and a "tree-hopper" in the Amazon region, the latter very closely imitating the former as it carries on its back a leaf, which it has cut for food.

Why all this counterfeiting in nature? Of what advantage is it to two animals to be almost exact replicas of one another? Or is it counterfeiting? May not these remarkable resemblances be mere accidents of variation, after all? The Darwinians are, as usual, ready with an answer. According to Bates, a very real advantage in the life and death struggle of the animal world is afforded certain innocuous species by their resemblance to other species which are protected from their enemies by foul taste, or odor, or other unpleasant quality. A bird which has learned to respect a wasp by reason of its sting, will be very wary about seizing a fly which resembles a wasp, even though the former might prove a delicious morsel, did the bird only know it, while the "tree-hopper" is protected by its resemblance to a leaf-cutting ant, because of the bitter taste of the latter.

Occasionally two species of insects, each protected by some disagreeable quality, resemble each other. What advantages here, if both are self-protected species, in mutual resemblance between them? But the staunch Darwinian is at no loss for an explanation; for, he argues, if two unpleasant insects look alike, their enemies will have only one pattern of color to learn in order to avoid them both; whereas if they each had a different pattern they would have two patterns to learn, and in doing so would sacrifice twice as many insects as under the present arrangement.

There are a few species of animals which wear a white patch on the rump or tail; for example, the white tail of some species of deer and rabbits and the white rump patch of the antelope. Could anything so conspicuous be without significance? Certainly not, according to the Darwinians, for were it not for such "recognition marks," how could the young follow their mother or the herd its leader, when pursued by some swift and savage foe?

There are yet other instances of striking color which are not covered by any of the explanations which we have given so far. Why should the males of many birds be so splendidly attired that "even Solomon in all his glory was not arrayed like one of these"; while the females must be satisfied with a modest coat of drab or brown? The male scarlet tanager in flashing livery of black and scarlet, the male of the rose-breasted grosbeak with its breast of gorgeous rose, and the saucy little male goldfinch in coat of black and yellow, are



THE ANTELOPE

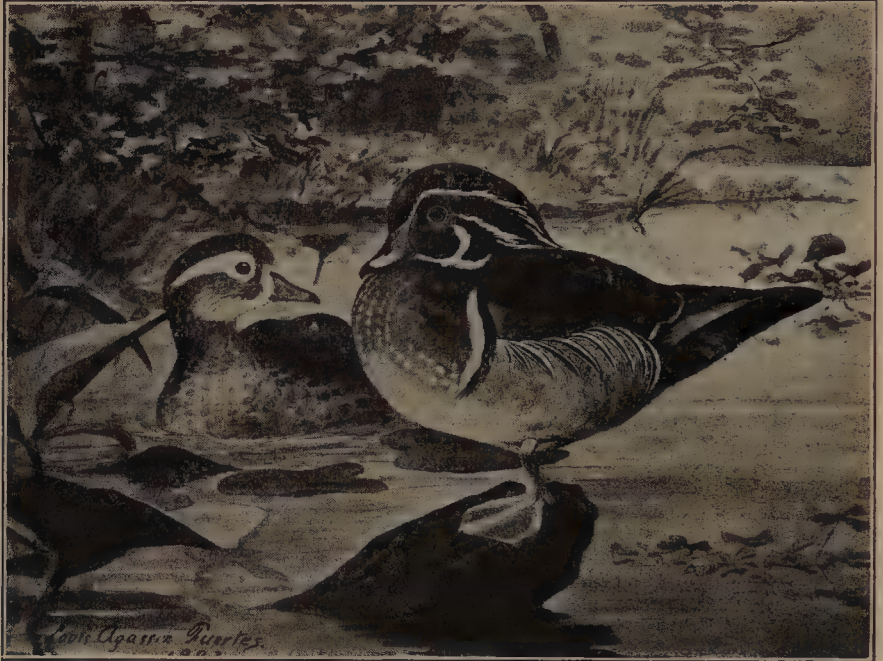
Which carries a recognition mark upon its rump. A vanishing species which once thronged our western plains.

Courtesy of the National Zoölogical Park.

among the most striking and beautiful objects in nature; while the females must be content with quiet colors, rendering them wholly different in appearance from their mates. Once again the Darwinian comes to rescue us from our dilemma with his theory of sexual selection, which was proposed and ably defended by Darwin himself in his "Origin of Species."

"This form of selection depends, not on a struggle for existence in relation to other organic beings or to external conditions, but on a struggle between the individuals of one sex, generally the males, for the possession of the other sex.

The result is not death to the unsuccessful competitor, but few or no offspring. . . . Generally, the most vigorous males, those which are best fitted for their places in nature, will leave most progeny. But in many cases, victory depends not so much on general vigor, as on having special weapons, confined to the male sex. A hornless stag or spurless cock would have a poor chance of leaving numerous offspring. Sexual selection, by always allowing the victor to breed, might surely give indomitable courage, length to the spur, and strength



MALE AND FEMALE WOOD DUCKS

Showing sexual differences in color, from an illustration by Louis Agassiz Fuertes.

Courtesy of the U. S. Bureau of Biological Survey.

to the wing to strike in the spurred leg, in nearly the same manner as does the brutal cockfighter by the careful selection of his best cocks. How low in the scale of nature the law of battle descends, I know not; male alligators have been described as fighting, bellowing, and whirling around, like Indians in a war-dance, for the possession of the females; male salmons have been observed fighting all day long; male stag-beetles sometimes bear wounds from the huge mandibles of other males; the males of certain hymenopterous insects have been frequently seen by that inimitable observer M. Fabre, fighting for a particular female who sits by, an ap-



SEXUAL DIFFERENCE IN BEETLES

The males to the left, and females to the right. From Darwin's "Descent of Man," D. Appleton and Company.



SEXUAL DIFFERENCE IN FISH

The male above, the female below. From Darwin's "Descent of Man," D. Appleton and Company.

parently unconcerned beholder of the struggle, and then retires with the conqueror. The war is, perhaps, severest between the males of polygamous animals, and these seem oftenest provided with special weapons. The males of carnivorous animals are already well armed; though to them and to others, special means of defense may be given through means of sexual selection, as the mane of the lion, and the hooked jaw to the male salmon; for the shield may be as important for victory as the sword or spear.

Amongst birds, the contest is often of a more peaceful character. All those who have attended to the subject, believe that there is the severest rivalry between the males of many species to attract, by singing, the females. The rock-thrush of Guiana, birds of paradise, and some others, congregate; and successive males display with the most elaborate care, and show off in the best manner, their gorgeous plumage; they likewise perform strange antics before the females, which standing by as spectators at last choose the most attractive partner. Those who have closely attended to birds in confinement well know that they often take individual preferences and dislikes: thus Sir R. Heron has described how a pied peacock was eminently attractive to all his hen birds. I cannot here enter on the necessary details; but if man can in a short time give beauty and an elegant carriage to his bantams, according to his standard of beauty, I can see no good reason to doubt that female birds, by selecting, during thousands of generations, the most melodious or beautiful males, according to their standards of beauty, might produce a marked effect."²

These various theories of animal color are unfortunately mainly founded on an "anthropomorphic" basis. If it is difficult for us to discover the frog in the grass or a lizard on a stump, assuredly it must be so likewise to the natural enemies of these creatures. If a butterfly or a toad has a foul taste, or an unpleasant odor to man, it must impress its enemies with the same unpleasant feature. If the white tail of the rabbit renders him easier for us to follow as he dashes away, it must also aid the young in their flight to keep near the mother. It does not follow however that because an object is difficult for man to see, it is likewise difficult for the eye of bird or beast to follow it, or because another object is unpleasant to man's senses, that it is also unpleasant to those of the creatures of the wild.

Recent experiments tend in particular to refute the theory of warning color. This is based very largely, though not

² Darwin, "Origin of Species," 6th ed., pp. 108-109. By permission of D. Appleton and Company.

exclusively on the colors of certain butterflies, whose natural enemies are assumed to be birds, to which they are supposedly obnoxious through unpleasant taste or odor. Two distinct assumptions are involved in the theory—first that butterflies are the natural prey of birds, and second that certain species are avoided by the latter by reason of some unpleasant characteristic. The first of these hypotheses is founded on very slender evidence. There are, it is true, a few scattered records of birds feeding on butterflies in nature, but, considering the extent to which birds and butterflies have been studied in the field, these records are few and far between. But, confronted by the paucity of evidence in one direction, the ever facile mind of the Darwinian turns immediately in another. Butterflies carry with them, he maintains, evidence of the peril in which they live, in the form of nicks in the hind wings; which, since they frequently have the form of a bird's beak, must be the result of unsuccessful attacks by birds, from which the butterflies have made hairbreadth escapes. But if one studies a series of butterflies taken in late summer or early autumn, he will probably find the wings of nearly all of them torn and broken in such a way that only a little Darwinian imagination is required to conjure up out of all these tattered wings a tale of the tragedies which might have been. The more natural interpretation is however that the butterflies' wings merely show the result of the wear and tear of a summer's flight through field and thicket.

If butterflies are the natural prey of birds an examination of their stomachs should prove it. Such examinations have been made for many years by the U. S. Biological Survey, in the study of the relation of birds to agriculture, but out of some 80,000 examinations made butterfly remains have been found in but very few.

The second point involved in the theory has rather more evidence in its support. There are a number of observations on record of birds refusing the strikingly colored and evidently distasteful species of butterflies. These observations cover not merely butterflies but other insects also.

But there is also much evidence to the contrary. Thus Judd, in a number of feeding experiments, has shown that obnoxious forms such as various species of bugs (Hemiptera) whether warningly colored or not are occasionally eaten, as well as stinging insects such as bees. Judd's results must however be accepted with caution, having been obtained with caged birds. It is not certain that captive animals show normal tastes. In some of my own experiments I have found that young birds will eat almost anything which is offered

them, and in some cases will pick up bits of leaves, etc., which never in any likelihood form part of their normal food under natural conditions. Stomach examinations however show that supposedly disagreeable insects form a considerable part of birds' food. Thus hairy caterpillars, stinging bees and wasps, ants and species of foul-tasting or smelling bugs and beetles are eaten by a great variety of birds.

Greater doubt is cast upon the theory of warning color by the work of Reighard at the Dry Tortugas. These are isolated groups of coral islands lying off the Florida coast, and surrounded by coral reefs. Inhabiting these latter are many species of brilliantly colored fishes, which supposedly come within the category of warningly colored forms. Living in the same reefs is a predaceous fish, the gray snapper. Reighard has shown that the brilliantly colored fishes of the reefs are readily eaten by the snapper, once they are outside the protection of the reefs. That the snappers can distinguish different colors however and can learn to associate them with unpleasant tastes was proved by attaching the stinging tentacles of a jellyfish (*Cassiopea*) to a small fish upon which the snappers commonly feed, and coloring the prey red. After several unpleasant experiences the snappers learned to leave the red fish severely alone, whether with or without the tentacles attached, while they took fish which were colored white even though the stinging tentacles were attached to them.

Longley also has made extensive studies of these fishes, as a result of which he finds that the apparently conspicuous and contrasting colors of so many coral reef fishes are really protective, harmonizing their possessors with their surroundings and have no relation to warning color whatever. Longley strongly inclines to the hypothesis of Thayer that the greater the contrasts in an animal's color, the more readily will it harmonize with its background, a principle most strikingly illustrated in the bizarre effects of our camouflaged ships in the recent war.

CHAPTER XIV

Aquatic biology. Oceanography, life of the sea and its environment. Biology of inland waters. Methods of studying aquatic life.

The development of aquatic biology, especially of its marine phase, both here and abroad, has gone very nearly hand in hand with the development of interest in the fisheries. Perhaps nowhere else in biology has there been a better recognition of the dependence of commercial interest upon scientific knowledge—of the national stomach upon the national brains. The recognition of this fact in Europe led to the establishment of the marine stations at Kiel, Lowestoft, Boulogne and elsewhere, and to the development of the International Council for the Investigation of the Sea, conducted jointly by Great Britain, Norway, Sweden, Denmark, Holland, Germany, Belgium and Russia, an enterprise which before the great war was achieving results of vast scientific and practical value, and which it is to be hoped will soon be re-established, following the advent of peace.

The earliest attempts at exploration of the sea were observations on currents, tides, waves and temperature. There were however occasional efforts to determine the depth of the ocean by the earlier navigators, some of them undertaken with very ingenious, but not very successful apparatus.

The first map of the Gulf Stream was published by Benjamin Franklin in 1770, and a few years later temperature observations along the north Atlantic coast, were made by the Englishman, Blagden.

The U. S. Exploring Expedition in 1839-42, under the direction of Captain Wilkes, accompanied by the geologist Dana, made a number of deep-sea dredgings. The U. S. Coast Survey has made important contributions to our knowledge of the sea since the early part of the last century and the first successful apparatus for deep sea sounding was devised by Midshipman Brooke of the U. S. Navy. As the result of dredgings conducted by the Survey off the coasts of Florida and Cuba between 1867 and 1870, under the direction of the elder Agassiz, he reached the conclusion that former oceanic and continental areas were similar to those of the

present. Expeditions by several ships of the U. S. Navy and Coast Survey during the latter half of the last century have made valuable additions to our knowledge of the sea, among which may be mentioned the cruises of the "Blake" in the Caribbean Sea and the Gulf of Mexico from 1877 to 1880 under the direction of the late Alexander Agassiz, of the Museum of Comparative Zoölogy of Harvard University, and son of the great Swiss-American naturalist.

The establishment of the U. S. Fish Commission in 1871 early led to marine expeditions conducted under its auspices,



THE "ALBATROSS" OF THE U. S. BUREAU OF FISHERIES.

The pioneer American vessel engaged in oceanography. She was in charge of Alexander Agassiz during his cruises on the Pacific and has added much to our knowledge of the fisheries of the Pacific Coast, especially Alaska. After Smith, in *Bulletin of the U. S. Bureau of Fisheries* for 1908.

although partly financed by private money. The Commission was at first dependent upon vessels loaned to it by the U. S. Revenue Cutter Service, the Navy, and the Coast Survey, but in 1880 it acquired for its own use the steamer "Fish Hawk," which has since then been used on the Atlantic coast, partly for scientific investigations and partly as a floating fish hatchery; and two years later the "Albatross," which has been mainly employed in scientific and practical investigations on the Pacific Ocean, but during the recent war was in naval service on the Atlantic, and is at present temporarily out of commission at Baltimore.

Much of the hazard of the fisherman's trade is due to the

dangerous construction of his craft. In order to minimize so far as possible this danger the Commission constructed a model fishing schooner, the "Grampus," designed to overcome some of the defects in the older type of boat hitherto in use. The construction of this vessel has largely revolutionized that of the New England fishing boats and some idea of its influence in the saving of wealth and life may be gained by comparing the loss of 82 vessels from Gloucester alone during the decade previous to 1883, at a cost of \$400,000 and 895 lives, with that of the period from 1898-1907, in which only one-fourth as many vessels and lives were sacrificed. Besides serving as a model fishing boat, the "Grampus" has also been used in scientific investigations along the Atlantic coast.

In addition to the more extended researches of the "Albatross" in the Pacific considerable local work has been done by the boats of the marine station of the University of California, now known as the Scripps Institution, and some desultory observations have been made by occasional workers elsewhere. There has been however no systematic or concerted program by American workers in the great field of oceanography similar to that undertaken by the European countries already mentioned prior to the war, a neglect which is scarcely pardonable in view of the richness and extent of our oceanic domain, the ever-growing cry for food, and the financial resources of our nation both public and private.¹

The biology of inland waters has also been largely dependent upon economic interests, in part those furthered by the Bureau of Fisheries, and in part by various state surveys.

The work of the oceanographer as related to biology is concerned with investigating the physical and chemical conditions of life in the sea, and in determining how marine life is related to these conditions. The economic phase of the science deals with those forms useful to man for food or otherwise, in their relation to their environment both physical and biological, and endeavors to discover the best means of obtaining, protecting and increasing them. A consideration of this latter phase may best be left to another chapter.

In a review like the present we must needs pass over much that is interesting and important in this great field, touching briefly however on some of its most salient features.

If one were to construct a model of the earth with a diameter of six feet, a scratch on the surface of the globe, about one-tenth of an inch deep would represent the greatest irregularity of the earth's surface, from the summit of Mt. Everest, rearing its yet unconquered front nearly six miles into the clouds, to the abysmal depth of 31,614 feet or 2,600

■ Plans are at present on foot, looking toward such an end.

feet greater than the height of Everest, which is the greatest depth yet recorded in any ocean. This depth was found by the U. S. S. "Nero," in the north Pacific near the island of Guam.

The floor of the ocean is covered with fine ooze composed largely of the fragments of shells of many kinds of animals and some plants, predominant among which in many places



A RADIOLARIAN

Courtesy of the American Museum of Natural History.

are the minute and wonderfully sculptured shells of unicellular animals, Radiolaria, and Foraminifera, which in life are floating at the surface of the sea. The shells of these minute creatures often make up so large a part of the bottom deposits, that the latter are named from them. One of the commonest of them is Globigerina, which has given its name to extensive bottom deposits in the sea. The shells of certain small species of molluscs, the pteropods or "wing-

feet," so named from the wing-like expansions of the muscular foot which protrude from the shell and by means of which they swim, make up the great mass of the ooze in other places, hence the name pteropod ooze, while the marvellously beautiful little diatoms, so named from the two parts of the shell, which fit together like the two halves of a pill box predominate in other places, producing the diatom ooze, which is common in the circumpolar regions, both north and south.

Not only do the shells of animals and plants settle to the ocean floor, but contained within these shells are their dead bodies, which serve as food for bottom living animals, whose digestive tracts are found full of mud from which the suitable food material is digested and absorbed, the greater amount being discharged as waste. It is thus that oysters and clams are nourished, and as we enjoy our "bluepoints" and "little necks," on the half shell, we may relish them all the more to know that we too are scavengers of the sea.

Far to the eastward from our southern coast extends the "Sargasso Sea," so called from the sargassum weed, which floats in great masses at the surface of the ocean, and is borne out from the warm waters of the Gulf of Mexico by the Gulf Stream to the northeast. Making its own food from the inorganic materials in the sea, by means of the action of sunlight on its chlorophyl, it contributes largely through its death and decay to the food supply for animals upon the ocean floor. Then too organic dust, containing the decayed remains of land plants and animals, is carried by wind and current far from land and gradually settles to the bottom as it goes. How far this detritus may be carried out to sea we do not know. It probably varies greatly in different oceans, dependent on wind and current. Volcanic dust however has been carried around the world.

What are the conditions of life for the "dwellers in the deep"? How do they "live and move and have their being" in the abysmal depths of the sea? While by far the greater number of marine organisms are found in comparatively shallow water, or floating and swimming freely at the surface, there are a few "dwellers in darkness," who, in the struggle for existence, have sought out the "fathomless depths" as an abiding place, there to live their lives unknown, save when the trawl of the explorer brings them forth from their retreat.

Even at depths of over 24,000 feet life has been found within the sea. At such a depth any object is under a pressure of over 10,000 pounds per square inch. The pressure on the ordinary concrete foundation for a bridge pier or a New York "skyscraper" is only 350 pounds per square inch, so that some of the inhabitants of the sea have to

sustain roughly three times the pressure on the foundations of the Woolworth Building or the Metropolitan Life. To withstand such a pressure the body of an animal would have to be surrounded by an exceedingly strong shell, or else it must be of such a character that the pressure is easily rendered the same within and without. The latter method is the one which Nature has adopted, and the bodies of deep sea animals are so soft and permeable that they lose their



DEEP SEA FISHES AS SEEN AGAINST A LIGHT BACKGROUND.

Photograph of a group in the American Museum of Natural History in New York.

Courtesy of the Museum.

shape very easily when brought to the surface and are consequently hard to preserve in their natural form.

Below depths of three thousand feet light is virtually absent in the sea. Animals therefore living below this comparatively shallow depth are in perpetual darkness, save for such light as they themselves generate. Many of these deep sea forms carry their own lanterns about with them in the form of phosphorescent organs. The firefly is an object of common experience to many a country dweller, but only the ocean voyager or the inhabitant of its shores, who has seen the

crest of a wave break into myriad opalescent drops, can fully appreciate the beauty and the wonder of this strange, uncanny light. The physiology of light production in animals is not yet well understood. It is known to be due however to some secretion which combines readily with oxygen, this action producing the light. Phosphorescence is by no means limited to deep sea animals, nor do all of the latter possess it.

One of the most interesting cases of light production is



DEEP SEA FISHES AS SEEN AGAINST A DARK BACKGROUND

Photograph of a group in the American Museum of Natural History in New York.

Courtesy of the Museum.

that of the deep sea angler fish, *Gigantactus*, where the snout is modified to form a luminous organ, suspended on a stalk above the head of the fish. This organ is supposed to act as a lure to attract smaller fish which readily fall victims to the angler's appetite.

The occurrence of eyes in deep sea fishes forms a very perplexing problem. In some the eyes are large, and in others extremely small or entirely lacking. By analogy with the cave dwellers among land and fresh water animals, we should expect the deep sea fishes to be blind. But on the other hand



TWO DENIZENS OF THE DEEP

LEFT. An angler fish which carries a lure on its head to entice its prey within reach of its capacious jaws. From the "National Geographic Magazine," Vol. 21.

RIGHT. *Chiasmodon niger*, champion cannibal among fishes. From Murray, "Depths of the Ocean,"

By permission of the Macmillan Company.

of what advantage would it be to a species of fish to have light forming organs, and no means of seeing them? The whole question of sight organs and light production by deep sea forms is a veritable "Chinese puzzle," which no one has yet had ingenuity enough to solve. It is not merely a ques-

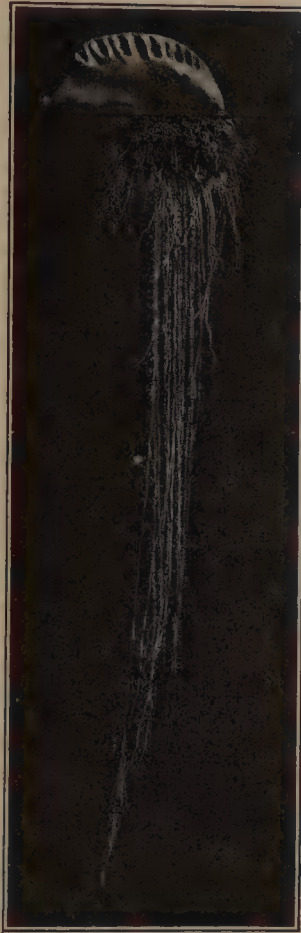


GIANT SQUID

And skin of whale showing marks of giant squid tentacles. From Murray, "Depths of the Ocean."

By permission of the Macmillan Company.

tion of two animals of the same species seeing and recognizing one another; but of one species finding its prey and another escaping from its enemies; while in many cases light produc-



THE PORTUGUESE MAN OF WAR, AN ANIMAL "U-BOAT"

The balloon-like float filled with gas secreted by its walls floats at the surface of the sea, so that the colony is carried hither and yon by wind and tide. Each of the thread-like processes pendent from the float is an individual member of the colony having its own special function to perform, some having stinging cells for capture of prey, others serving as feelers and still others as feeders, the mouths and stomachs of the colony. By contraction of the float the gas is expelled and the animal can submerge. A southern form, it is often carried by the Gulf Stream into the North Atlantic.

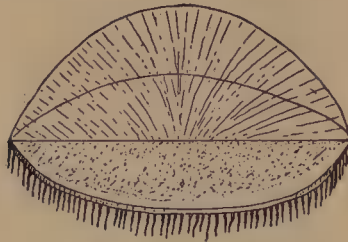
Courtesy of the American Museum of Natural History.

tion may be purely incidental to other processes in the life of the animal. And further, the same ends are attained in different ways in different species. Nature knows "more

than one way to kill a cat," and, *vice versa*, to save its life and preserve its kind.

The depths of the sea are the scene of many a drama. If Science but had the key to Davy Jones' Locker, what a wealth of secrets, tragic as well as comic, she might reveal! There is the fate of the flatfish who fell over on his side before he grew up, and remained lop-sided ever after. And there is the champion cannibal of the animal world, *Chiasmodon niger*, who swallowed his elder brother, acquiring thereby a portly figure of which the most accomplished gourmand might well be proud.

Many a terrific battle has been fought upon the sea—titanic struggles of giant squids and mighty whales, battling to the death. Some of these squids have a spread of tentacles of over eighty feet, and the whales, which are probably the invariable victors in these encounters, bear with them well-



VELELLA

Original from a specimen in the zoölogical collection of the University of North Dakota.

earned decorations as evidence of their prowess, in the form of circular scars left upon the skin by the suckers of the squid.

Floating at the surface of the sea is a host of beings large and small, "creatures of circumstance" driven hither and yon by "every wind that blows." Delicately tinted jellyfish, Vellellas with their tiny sails, the "Portuguese Man of War" with its balloon-like float and its vicious stinging tentacles trailing below, the rotund sunfish, and a legion of crustaceans, molluscs and many others, live at or near the surface. What enables them to float so easily? Some are lighter than the water, as the jellyfish and the sunfish, with its jacket of fat beneath the skin. Still others have floating sacks or bladders containing gas, like the "Portuguese Man of War," while others still, the great majority, have projections of some sort, which increase their "specific surface," i. e., the ratio between surface and weight, and hinder their sinking. A tin plate will sink slower than a leaden bullet



ABOVE. AN OCEAN SUNFISH. Photo by C. H. Townsend.

By permission of the New York Zoölogical Society.

BELOW. A CRUSTACEAN LARVA, showing flotation spines. From Steuer, after Claus.

of equal weight, and a feather or sheet of paper falls more slowly through the air than a tiny lead shot, which weighs no more. Wonderfully varied and beautiful are the devices with which Nature has furnished both plants and animals to buoy them in the water. Many diatoms are provided with long and exceedingly fine spines. The Radiolaria previously mentioned also have numerous spine-like processes projecting from their shells. Many molluscs have plate or wing-like extensions of body or shell, secretions of slime, or air chambers which aid in flotation. But perhaps the most beautiful floating structures in the animal kingdom are found in the Crustacea where antennæ, feet and tail may be greatly lengthened and finely branched, forming long, feathery processes which, when extended, offer great resistance to the water and serve admirably in keeping the animals afloat.

While many marine animals, and the same is true of fresh water forms, are inactive swimmers, floating idly at the surface of the sea; or living a monotonous existence hidden away in some obscure niche of coral reef, or groveling on the ocean floor; there are others, mariners bold, who fare forth in quest of prey, making long journeys across the sea. Naturally the chief of these are the whales and fishes, most of whom are powerful swimmers, which follow their food from place to place and whose presence can usually be predicted from the presence of the latter.

Experimental evidence of the migration of fishes has been obtained in recent years by the International Council for the Investigation of the Sea by marking fish, and then recording so far as possible the number of marked fish caught. This has also been practised on our Pacific salmon and a similar method has been employed by American ornithologists for studying the migration of birds. This has been employed especially in studying the spawning migration of fish, and it has been shown for example that the Iceland plaice migrate hundreds of miles to and from their spawning grounds.

In 1888 and '98 two whales were taken off the coast of northern Norway, each of which contained bomb lances of American manufacture. These lances had evidently been used by American whalers, which do not ordinarily cruise off the Norwegian coasts, and the capture of whales containing these lances in Norway is probable evidence of long journeys made by them.

Even more interesting than the more or less sporadic movements of aquatic animals in search of food are their periodic journeys to and from their spawning grounds. The annual run of the salmon, which is described in another chapter,

produces one of the principal industries of the Pacific Coast, while the migration of the shad in the rivers of the Atlantic Coast, in former days brought wealth to the fisherman, and delight to the palates of those fortunate enough to feast on this delicious food. Now unfortunately owing to various factors this fishery is much decreased.

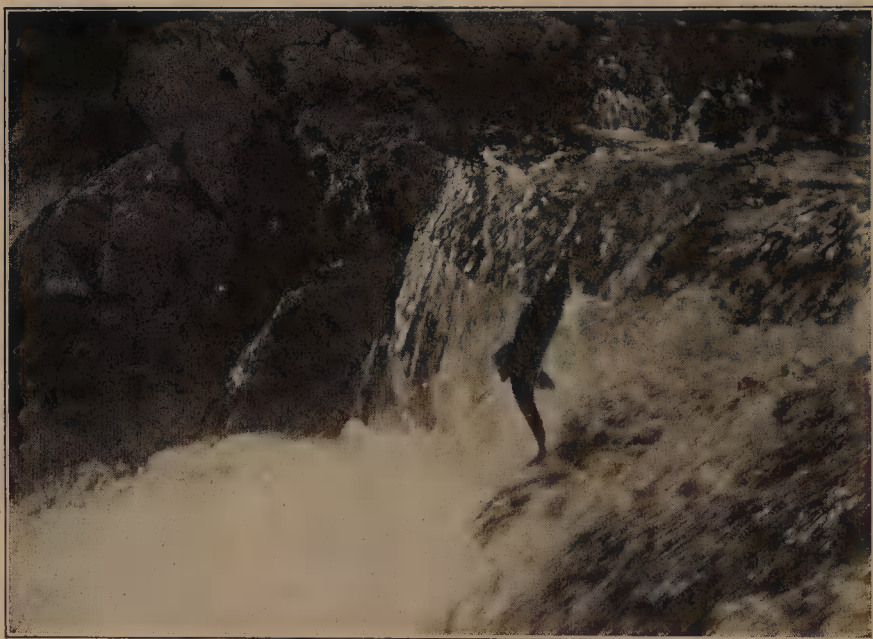
The underlying cause of these breeding migrations of fish is still as much an unsolved problem as is that of bird migration. We have already seen the profound influence which internal secretions exercise upon the metabolism and growth of animals. We have also seen how external chemical agents may influence the reactions of animals (i. e., light responses of *Daphnia*, etc.). The cause therefore of these movements of certain fish is undoubtedly to be sought in the action of a secretion of the sex glands causing primarily restlessness and movement from place to place on the part of the fish, and secondarily a change in response to the chemical environment. Thus the ripening of the sex cells in an adromous fish such as salmon and shad with the coincident formation of some internal secretion by the sex glands, probably induces restless wanderings on the part of the fish, in the course of which they come into regions of fresh water discharged by some river. Turning in the direction whence the fresh water comes, they are guided to the mouth of the river, which they ascend, due to their inclination to swim against the current. The restlessness which brings them originally into fresher water finds further expression in the leaping of the salmon when they encounter a fall on their course up stream. This instinct develops even in fish which have been kept from birth to maturity in ponds, for such salmon have been known to leap out of the water onto the bank to die.

After spawning and cessation of the internal secretion the fish lose their tendency to swim up stream, and are either carried helplessly down by the current, dying as they go, in the case of the adult salmon on our Pacific Coast, or in the case of the young salmon and the young and adults of other fish (sturgeon, shad and Penobscot salmon) they swim with the current back to their home in the sea.

Eels have a different history, living in fresh waters and descending the rivers to the sea to spawn. The mysterious habits of the eel have given rise to some very curious tales of early writers, according to whom eels are spontaneously generated in mud and elsewhere, or are formed from horse hair, old eel-skins, etc. After spending several years in fresh water, the ripening of the sex organs probably induces the wandering habit in the eel, and it descends the river to the ocean, where it spawns in realms unknown, but in any event



SALMON AT BASE OF FALLS EN ROUTE TO THEIR BREEDING GROUNDS IN
ALASKA



"CAUGHT IN THE ACT," A LEAPING SALMON
Courtesy of the U. S. Bureau of Fisheries.

in water more than 3,000 feet deep.² Where the eggs are laid is not known, but they hatch at the surface of the sea, into ribbon-shaped, transparent larvæ of about the thickness of a visiting card. After about a year's time, during which they are said to take no food, the larvæ lose their ribbon shape and assume the eel-like form. They now approach the coasts and ascend the rivers in large numbers, forming what are known as the "eel-fares" of late winter or early spring. Like the Pacific salmon, the adults die after spawning, though the manner of their demise is unknown.

But the spawning and feeding migrations of marine animals are not their only active movements. Many species seek the deeper layers by day, coming to the surface at night. The depth of this diurnal movement varies for different species, but does not in general exceed 100 to 150 feet. In some species, the wandering habit is restricted to the young, while in others migrations are performed by the males only. Similar diurnal movements occur in fresh water animals, as already noted.

There are also many species in which the young are found at one level, while the adults occur at some other. This is notably true of many bottom-living fishes, such as the cod and halibut, whose eggs and young are found only at the surface. Here it may be that differences in specific gravity at the different ages explain these differences in distribution.

A word here may not be amiss as to the tools of the oceanographer. By what means has our knowledge of the depths of the sea been obtained? In the study of oceanography, as indeed in many other of the complex fields of modern science, the biologist must be a physicist and chemist as well. One of the most important implements of the oceanographer is his sounding line. This is used not alone for measuring depth but for carrying instruments of various sorts. In the earlier deep sea expeditions, notably those of the British ship "Challenger" (1872-'76) rope lines were used for sounding. On account of the heavy strain (the weight of 20,000 feet of the line itself in water was nearly 250 pounds) a rope one inch in circumference was used. The necessary length of this rope (over 30,000 feet) rendered it awkward to handle and necessitated large space for its accommodation. For trawling still heavier lines (up to three inches in circumference) were required, which were still more difficult to handle and to store. At the time of the "Challenger" expedition, Sir William Thompson (Lord Kelvin)

² Recently the Danish oceanographer, Johannes Schmidt, has apparently discovered the spawning grounds of both European and American eels southwest of the Bermuda islands.

was designing a sounding machine to be employed with wire line, but wire was first actually used for this purpose by two American captains, Belknap and Sigsbee, of the exploring vessels, "Tuscarora" and "Blake" respectively. They employed piano wire about one-tenth of an inch in circumference, with an obvious saving of space. For trawling Sigsbee used a wire rope made up of forty-two piano wires twisted about a tarred rope at the center.

For sounding at great depths a heavy weight is necessary to hold the line plumb against the currents of the sea and



SIGSBEE SOUNDING MACHINE IN USE ON THE "ALBATROSS"

Courtesy of the U. S. Bureau of Fisheries.

the drift or swing of the ship even when at anchor, and this descends at a rapid rate. With a weight of thirty to forty pounds, the line runs out at the rate of about seven feet a second, while with weights up to four or five hundred pounds, which are employed in deep sounding, the speed is much greater. The depth is determined from the number of revolutions of the wheel which carries the line, and the end of the sounding is noted by the sudden slackening of the speed of the line in its descent. This point is naturally very difficult to observe in a rapidly moving line. To overcome this difficulty sounding machines of various types have been devised, all of them founded on the principle of Lord Kelvin's original

machine, in which a counter-weight serves to check quickly the speed of the wire, when the sounding weight reaches the bottom. The types employed by the "Albatross" and other vessels of the U. S. Bureau of Fisheries, in which adjustable springs are used as brakes, instead of counter-weights, are known as the Sigsbee and Tanner machines from their designers, Commanders C. D. Sigsbee and Z. L. Tanner of the U. S. Navy. These springs also serve as "accumulators" to relieve sudden strains on the sounding line, due to tossing of the ship in rough weather.

Another means of checking the descent of the line is the detachment of the sinker when the bottom is reached. This is usually accomplished by means of a catch to which the sinker is attached. While the sounding line is taut this catch is automatically held in place, but when the former is slackened the catch drops, releasing the sinker and thereby relieving the pull on the line.

For taking samples of the bottom there is frequently attached below the sounding weight a metal tube lined with tallow, which is driven into the bottom by the impact of the sinker, and when drawn up retains some of the bottom material adherent to the tallow. Some samplers are made with valves at the upper and lower ends of the tube, which are automatically closed when the sample is taken, thereby preventing the escape of the catch. For taking larger samples of the bottom, devices similar to the ordinary grapple-dredge used in excavation work are sometimes employed.

The measurement of ocean currents is made with various types of current meters, some of which are constructed on the principle of the instrument used by the U. S. Weather Bureau for measuring the velocity and direction of the wind. These carry a vane or rudder for holding the meter in line with the current, and a series of revolving cones, the number of revolutions of which are transmitted by a telephone to the ear of the observer at the surface, and from their number per minute the velocity may be computed. In the Eckman current meter named from the Swedish naturalist, V. W. Eckman, which is much in use, both here and abroad, the velocity of the current is registered by the revolutions of a propeller, connected to a dial whose hands are turned by a set of cog-wheels, and the direction recorded by means of a magnetic needle, a box divided into thirty-six compartments, and a tube full of shot connected to one of the cog wheels of the dial. As the latter turns it feeds the shot into the needle box where it falls onto the middle of the needle, and then runs through a groove to drop into one of the thirty-six compartments, depending upon the position of the needle

in the box. Thus the direction of the current with reference to the magnetic meridian is recorded by the number of shot in the different compartments of the needle box.

The early oceanographers attempted to determine temperatures in the depths of the sea either by bringing up a sample of water from any given level in an insulated container and recording the temperature of the sample on the deck of the ship; or by insulating the thermometer itself so that it acquired the temperature of the water very slowly, leaving it for a time (several hours) at the desired level and then hauling it up very quickly, so that its temperature would change but slightly, if at all, in the ascent. The former method of taking temperatures was employed by Nansen on his polar expeditions and is still used to some extent, but the principal method at the present time is the use of some type of deep sea thermometer, which shall record the temperature at a given depth, and give the same reading when drawn to the surface. One of the earlier types of instrument employed, and the one used by the "Challenger" expedition, was a modification of the ordinary maximum and minimum air thermometer. For moderate depths, or in cases where the temperature changes uniformly from the surface downward, this type of instrument gives fairly satisfactory results; but for great depths, where the temperature does not change uniformly from top to bottom, the results are unreliable.

The later types of instrument used are all constructed on essentially the same principle. They consist of a thermometer with a neck which is twisted and very narrow just above the mercury bulb. This is enclosed in a jacket of very heavy glass hermetically sealed for protection against the enormous water pressure at great depths, the mercury bulb being surrounded by a special mercury jacket so that heat may be rapidly conducted between the former and the water. After lowering the thermometer to any given depth, it is reversed, or turned upside down by a special mechanism, when the mercury column breaks at the constricted point and drops to the opposite end of the tube, where the reading is given on a standardized scale. Before reversal the mercury can pass up or down the tube through the constricted neck dependent on the raising or lowering of the temperature; but after reversal and consequent breaking of the mercury column, no more mercury can pass through and the reading gives the true temperature except for a correction which has to be made. During the ascent of the thermometer, if the difference in temperature between air and water be considerable there will be a slight change in the volume of the broken off column of mercury and the reading will not be strictly accurate. A

correction can be made for this error however if the temperature difference be known, and so in one of the best types of instrument an accessory thermometer is mounted alongside the principal one, and thus the difference in temperature between the water and the air at the moment of reading can be taken and the correction applied.

The reversal of the deep sea thermometer is effected either by means of a small propeller which commences to revolve at the moment of raising the thermometer, or more usually by means of a weight or "messenger" which is dropped down the line and trips a catch, releasing a spring and upsetting the thermometer.

An estimation of the light penetrating the ocean may be made by lowering a white, or variously colored disk and noting the point at which it disappears, and *vice versa* by raising it from lower depths and noting the depth at which it can first be seen. By taking the mean of these two readings, and comparing it with some empirical standard, an estimate may be made of the transparency of the water. Electric lights are also employed for this purpose. A better method is the use of a photometer. Various types of these are employed, mainly designed on the principle of exposing photographic plates or films contained in a water-tight holder for varying periods of time and noting the density of the exposure after development. By comparing the density of these exposures with a standard set made in the air for different lengths of time, and taking into account the angle of the sun's rays with the horizontal and the turbidity and color of the water, an estimate may be obtained of the intensity of the total illumination at various depths. If it is desired to determine the relative penetration of different rays of light (red, green, blue), plates of colored glass, with a known capacity for absorbing (and therefore cutting off from the plate or film) certain rays and admitting their complementary rays, may be placed over it. Such an apparatus is crude at best, and it remains for the investigator of the future to devise a machine presumably of electrical construction, which will give an accurate determination of the light at different depths in the sea.^{2a} Even with the crude apparatus thus far devised however many interesting results have been obtained. The depth to which light penetrates the sea has already been mentioned. It has also been found that night-time comes much sooner for the children of the sea than for those of the air, for when the sun is yet many degrees above the horizon, the surface of the water acts as a mirror and totally reflects its rays. The

^{2a}Such apparatus has been devised, but has not yet come into general use.

reflection too is greater the greater the depth, so that at depths of a few hundred feet daylight may last but a few minutes, while at depths of more than 3,000 feet is a realm of perpetual night. The character of the sea also, whether smooth or rough, materially affects the results—the rougher the surface, the greater the number of mirrors, placed at many and constantly changing angles, and the greater the reflection of the light.



BIGELOW WATER BOTTLE

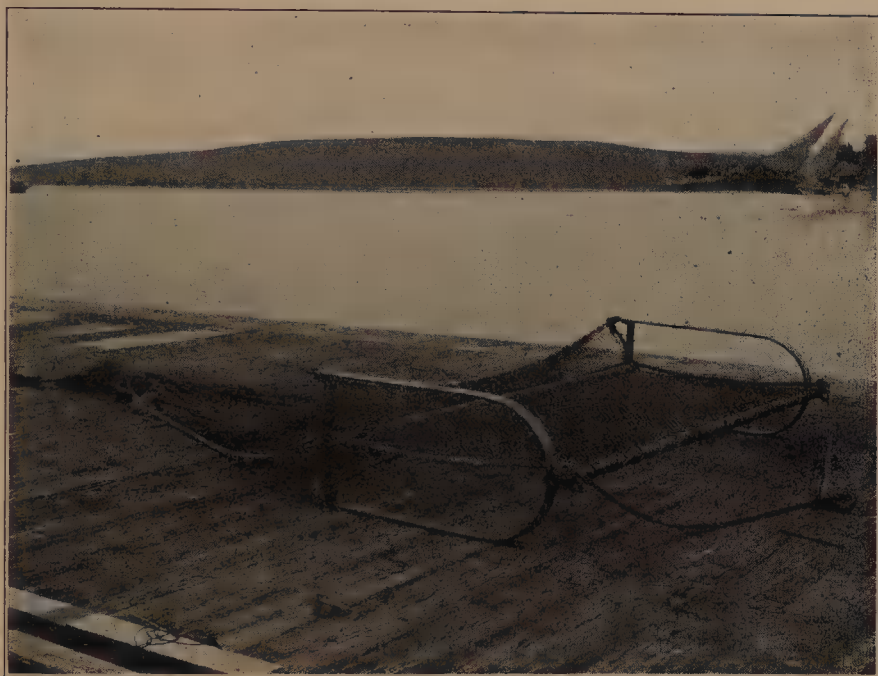
With deep sea thermometer reversed at the right, and "messenger" at top.

*Courtesy of the
U. S. Bureau of Fisheries.*

In collecting samples of water from various depths of the sea for chemical analysis, or for studying the microscopic life which it contains, various types of "water bottles" are employed. These can be closed at the desired depth and the contained sample then drawn to the surface for examination. The type in most common use at present is the Eckman bottle, another piece of apparatus designed by the naturalist, V. W. Eckman, to whom reference has already been made. This is a reversible instrument consisting essentially of a metal cylinder with two lids. In lowering the cylinder the two lids are held open so that water can pass freely through it. After it has reached the desired depth a messenger is sent down the line releasing a catch, when the cylinder upsets itself by its own weight and the lids are automatically closed at the same time. Held in the frame beside the water bottle is a reversible ther-

mometer, so that the apparatus serves for taking water samples and temperatures at the same time. A second messenger may be attached to the bottom of the frame in such a way that when the first messenger reverses the bottle, the second messenger is released, which in its turn reverses a second bottle and thermometer at a lower level, and so on. In this way a number of simultaneous observations may be made on a single line.

And how does the biologist obtain his knowledge of the denizens of the deep, of their comings and goings, their numbers and their whereabouts? The science of oceanography goes back to the earliest days when men went "down into the sea in ships" and cast their nets into the great waters, and the earliest instruments of the oceanographer were the compass, the plummet, the seine and the trawl. From all depths of the ocean are brought forth creatures, great and small. With harpoon and bomb lance, with heavy dredge



BLAKE DEEP SEA TRAWL

Courtesy of the U. S. Bureau of Fisheries.

and trawl, with hand line, seine and nets innumerable, down to those of the finest gauze used for sifting the whitest of our flours, man has searched the seven seas from top to bottom and from pole to pole in quest of hidden treasure.

The inhabitants of the ocean floor are brought up from their hiding place by means of dredge and trawl. The dredge is essentially a long rake or hoe attached to a stout iron frame, with a bag of steel or twine netting projecting behind. If the latter, it may be protected by an external covering of canvas open behind. As the toothed or straight bar which acts as rake or hoe is dragged over the bottom, it scrapes

up the surface of the latter, which is caught by the bag, the size of objects retained depending upon its size of mesh. The grapple-dredge or scoop may also be employed for this purpose, with the advantage of deeper penetration and consequent capture of burrowing animals which might escape the ordinary dredge. The trawl is constructed on much the same plan as the dredge except that it is designed to skim over the bottom taking those animals which live on, rather than in the latter. This is effected by supporting the bag, made of fish netting in the trawl, on runners like those of a sled, which slide over, rather than penetrate into the bottom. The smaller dredges in shallow water are operated by hand, but for the larger apparatus, which may bring up tons of material at one haul, heavy lines and steam winches, operated on the deck of a large vessel are essential.

For collecting the organisms present in the different levels of the sea a large variety of appliances have been devised, the details of which are too many and too intricate to describe here. For merely qualitative work, that is, for determining the kinds of organisms present at different depths, the appliances are relatively simple. Surface collections are made with tow-nets, of materials of various degrees of fineness, from coarse fish netting down to number 20 silk bolting cloth, with spaces only $1/400$ of an inch in diameter. These are usually of conical shape, with a large metal hoop at the opening and a small metal cup or bucket at the lower end, for holding the catch as the net is towed through the water. For collections at lower levels similar nets may be lowered to any desired depth and held horizontally while towed, by a weight attached to the tow-line just in front of the net. Or several of them may be attached to one main line at any desired points by means of side lines, the main line being carried down by a weight attached to its lower end. The kinds of organisms present at different levels may also be roughly determined by lowering tow nets to different depths and drawing them vertically to the surface and then comparing the catches taken in each. If, for example, certain organisms are present in the deeper hauls, which are absent in the shallower ones, it may safely be inferred that these occurred only in the lower levels. The relative abundance of organisms at different depths may also be roughly determined in this way.

Both of these methods however are open to the objection that the nets catch not only the organisms present at the particular depth which it is desired to study, but also at all depths intermediate between it and the surface, as the nets are drawn in. To overcome this difficulty various types

of closing nets have been designed, so constructed that they can be lowered closed to the desired depth, and then opened, either automatically by the pull on the net itself, or by a messenger sent down a cable, and closed again by a messenger, after which they are drawn to the surface without danger of mixing the catch with organisms present at other levels.

For qualitative work the loss of a few organisms is a matter of small consequence, and accordingly the net bucket



TOW-NETS

In use on the "Albatross" of the U. S. Bureau of Fisheries.

Courtesy of the Bureau.

is a simple affair merely screwed into a ring at the lower end of the net, or tied into the net itself. But for quantitative work every organism possible must be saved, and the bucket is accordingly more complicated, is readily detachable from the net, and can then be opened and drained into the container for receiving the catch.

The problem of determining the number of organisms present in a given volume of water, at any given time and place, is one of the most important, and withal difficult problems in oceanography. The quantitative study of the animals and plants in the sea is essential to a knowledge of their rate

of reproduction, their increase or decrease under varying conditions of environment and their movements from place to place. It is essential, not alone to a science of the sea, but also to a knowledge of its economic resources and the best means of their utilization.

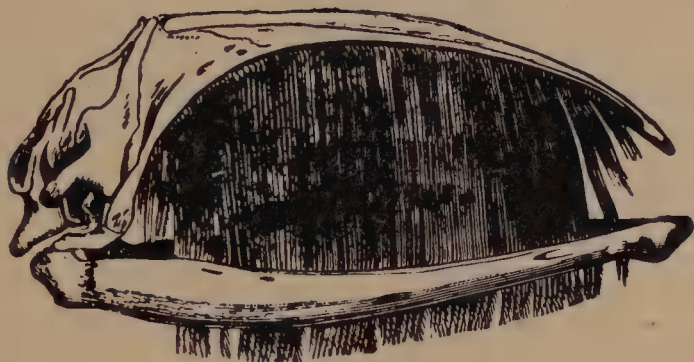
The dependence of fish and other animals, which man appropriates to his own use, upon the lower forms of life within the sea is matter of common knowledge. On our Atlantic Coast is an industry with a value in round numbers of \$3,700,000 annually, and giving employment to 5894 people, the menhaden fishery. The menhaden produces 6,600,000 gallons of oil every year which is used in making paint and varnish and for other purposes.³ After the oil has been extracted from the fish their remains are dried and ground up for fertilizer. They are also eaten to some extent. Professor Peck, in his study of the food habits of this fish several years ago, found that it fed exclusively on the minute plants and animals floating in the water. In feeding, the menhaden swims through the water with open mouth, at the rate of about two feet per second; and as it does so the water is filtered through the gills which form a fine sieve, allowing the water to pass freely but straining out the small organisms it contains, which are swallowed by the fish. In this way it filters about seven gallons of water per minute, obtaining from it about a cubic inch of food material in five minutes.⁴ From this it may readily be seen that the size of a menhaden's meal is limited only by its industry in eating it. The abundance of oil in this fish is due to its food, and thus we have a beautiful example of the value to man of the unseen and often unconsidered wealth of the waters.

The menhaden is not a large fish, weighing but little over a half pound on the average, but one of the giants of the sea, the blue whale, which reaches a length of nearly ninety feet and an estimated weight of seventy-five tons, and is probably the largest animal which ever lived, is likewise dependent on the small creatures of the sea for its food. The fast vanishing whalebone, which in years gone by played so large a part in shaping the fate as well as form of women, is obtained from the massive plates of bone-like baleen which fringe the palate of this and some other whales, and serve them as a strainer by means of which they obtain their food. The whale in feeding takes a few barrels of water into its capacious mouth; then as the mouth is closed and the tongue raised the

³ Data for 1912 from U. S. Bur. Fish. Doc., No. 811, 1917.

⁴ This amount was estimated by Professor Peck in the month of July at the mouth of the Acushnet River at New Bedford, Mass. It would naturally vary greatly at different seasons and in different places.

water is forced out through the baleen sieves, while the little animals it contains are held and then swallowed by the whale. The mouth of a whalebone whale is a wonderfully efficient mechanism. Were the whalebone stiff and inelastic, retaining a fixed position in the mouth of the whale, when the mouth was opened there would be left a wide space for the escape of the water between the strainer and the lower jaw. But the plates are both pliable and elastic folding backward in the mouth when the jaws are closed and springing into position when these are opened "like a bent bow," thus closing completely the mouth opening. But the tips of the plates are thin and easily bent, and were they not protected in some way might be bent outward by the force of the water when the jaws are closed, allowing some of its contents to escape. To guard against such a mishap Nature has provided the whale with a large lower lip, which overlaps the tips of the plates and holds them in place.



JAWS OF WHALEBONE WHALE

From Sedgwick after Cuvier in "Règne Animal."

Even man has tried the plankton of the sea and found it good, as testified by no less a personage than the Prince of Monaco himself, who found that the plankton copepods, when roasted in butter, made very good patties.

About thirty years ago it occurred to the German zoölogist, Hensen, to study the productivity of the sea as a source of human wealth, much as one would study the productivity of the land. Hensen thought of this productivity in terms of the smaller forms (chiefly microscopic) of plant and animal life, which constitute the food of fish, and which he named plankton from the Greek word *planktos*, wandering. In order to study its abundance, he constructed a net which is known from its inventor as the Hensen net. This consists of an inverted canvas half cone at the top supported by two rings,

to the lower and larger of which is attached the net proper, composed of fine bolting cloth, and terminating below in the detachable bucket which receives the catch. To relieve the strain on the silk this bucket may be supported by strings attached to the larger ring above and the silk may be surrounded by netting to protect it from injury. The object of the inverted cone is to insure the passage of all the water through the net which enters its mouth, a large part of which would otherwise flow over the edge of the net, rather than



HENSEN'S NET

For collecting plankton in the sea. From Steuer after Chun.

through its meshes, due to the resistance of the latter to the water. By lowering the net a given distance and then hauling it to the surface Hensen expected to filter all but the most minute organisms out of a column of water, whose height was the length of the vertical haul, and whose diameter was the diameter of the net opening. In this way he attempted to compute the number of organisms present beneath any given area of the sea's surface down to any given depth. Experiments have shown however that not all of the water assumed to pass through the net does pass through, and that

further this amount is a variable quantity depending on the rate at which the net is hauled through the water, the extent to which it has been used and various other factors, all of which introduce an error which is inconstant and is not exactly known.

Many kinds of quantitative plankton nets, both open and closing, have been designed since Hensen's original device was conceived. They are all however subject to the same errors as is Hensen's net, and for exact work, especially on the smallest forms or nanno-plankton (from the Greek word meaning dwarf) are very unreliable.

To obviate the uncertainty of the net method in quantitative plankton work, the water bottle described above has been used for small samples, while larger samples have been pumped from shallow depths and the water strained through a net to concentrate the catch. The former method is open to the objection that a small sample is not necessarily representative of a large area, as the organisms (especially the larger ones) may vary in abundance from place to place, while the pump method is only applicable to shallow depths, because of the great amount of hose required at lower levels, and is furthermore subject to one of the errors involved in the net method, namely that the smallest organisms in large measure press through the net, while a further error is involved in the tendency of many actively swimming, though minute animals, to swim away from the suction current created by the pump, and thereby give the eager and hard-working biologist the slip. For great depths and large catches therefore the net method, with all its faults, is the only practical one as yet devised.

But having made his collections how does the biologist determine the number of organisms which they contain? To do this the method in use among physicians for counting the corpuscles in the blood has been adopted. Knowing the amount of water filtered through the net, the catch is brought to a known concentration, say $1/50$ or $1/100$ part of the former, and a small quantity (usually one cubic centimeter) of the latter is placed in a glass cell on the stage of the microscope, and the total number of organisms (in the case of the larger forms) is counted. In the case of the very small organisms, such as the unicellular forms, the number present in several small parts of the cell is counted and by averaging these and multiplying by the ratio between the area of the cell and the total area of the parts counted, the number contained in the former can be estimated with a fair degree of accuracy. The size of the parts is determined by means of squares ruled on a small disk of glass in the eye-piece of the

microscope, each square covering a known area of the cell at a given magnification. Suppose, for example, the amount of water filtered through the net to have been 1,000,000 cubic centimeters (roughly 1100 quarts) and that the catch is contained in 100 cubic centimeters of fluid. Suppose further that the volume of the cell is one cubic, and its area ten square centimeters, and the area of each one of ten parts counted is $1/10$ of a square centimeter. If these ten parts contain 100 specimens of some species, then the number of individuals of that species in the 1,000,000 cubic centimeters strained by the net would be $100 \text{ (number of individuals counted)} \times [10 \div (10 \times 1/10)] \text{ (ratio of total cell area to area in which specimens were counted)} \times 100 \div 1 \text{ (ratio of volume of concentrated catch to volume of cell)} = 100,000$, or one in every ten cubic centimeters of the water filtered; assuming of course that the organisms are uniformly distributed through the concentrated sample and through the counting cell, an assumption which is only approximately true. The method of counting, like that of collecting, is subject to a large error and the whole method is necessarily a very approximate one. In the case of larger forms, which can readily be seen with the naked eye, such as shrimps, jellyfish and small fish, and which are never very numerous in these quantitative collections, the number taken in the entire catch is generally counted.

For counting the very minute animals and plants, if they are abundant, a more accurate method is the use of the centrifuge, by which all of the organisms may be obtained in the concentrate, if the speed of the centrifuge be sufficiently high and the time of centrifuging long enough. Centrifuges are now made which will run at a speed of 3,000-4,000 revolutions per minute and carry 100 cc. of water. In general however the centrifuge method is applicable only for the study of the most minute organisms in small samples of water. For general quantitative studies of the organisms present in the sea it is quite impracticable.

Yet another method of determining the number of organisms present in water, is the Sedgwick-Rafter method, so named from Professor Sedgwick of the Massachusetts Institute of Technology, the well-known sanitary biologist, and Mr. Geo. W. Rafter, C. E. This has been employed quite extensively for studying the organisms (especially the microscopic plants) present in drinking waters. In this method a given quantity of water, usually about a pint, is filtered through a plug of fine sand about three-fourths of an inch deep, which is held in the funnel-shaped end of a tall, narrow cylinder

by a perforated cork covered with a circle of fine bolting cloth. After the water has been concentrated to 1/50 or 1/100 part of its original volume, the cork is removed, the sand washed and the washings, containing the organisms to be counted, preserved. This method, like all others, has its advantages and disadvantages, principally the latter, but for general purposes is perhaps as little objectionable as any.

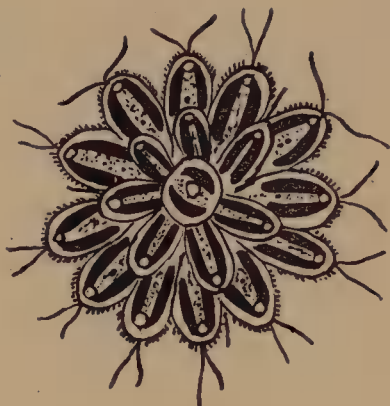
But the biologist relies not alone upon devices of his own cunning. In his search for the creatures of the sea he employs the whale as a retriever and in its capacious maw finds stores of undigested information. The most primitive, but withal the most efficient plankton trap known, is the pharynx of the ascidian or sea squirt, which is perforated by numerous minute openings through which water is strained, the animals and plants which it contains being retained in the pharynx to serve as the animal's food. By studying the stomach contents of these forms much has been learned of the microscopic life of the sea.

In studies of fresh water life many appliances are used similar to those employed for marine work, and but few of a special type are required. The methods employed here are necessarily simpler than those used in investigation of the sea, with its profound depths, its mighty waves and powerful currents. In work upon large bodies of fresh water however such as our Great Lakes, conditions are found resembling in many ways those of the sea, and here especially must the methods and apparatus of the oceanographer be largely resorted to. Such apparatus as is peculiar to fresh water research is described in various technical and special works, and does not call for special mention here.

Fresh water studies in the United States, apart from those of the most general character, have been prosecuted mainly by the Massachusetts State Board of Health, and the water works department of Boston, Mass., and Brooklyn, N. Y., the U. S. Bureau of Fisheries, the Illinois State Laboratory of Natural History and the Natural History and Geological Survey of Wisconsin. The first two of these agencies have studied the drinking waters of their respective communities primarily from the sanitary standpoint; the Bureau of Fisheries is interested primarily in the commercial utilization of our aquatic resources, while the other institutions have approached their problems from primarily the purely scientific angle with secondary reference to the practical results.

We are accustomed to think of the suitability of water for drinking and general domestic purposes in terms of bacterial and chemical character, overlooking the fact that there are

many plants other than the bacteria which may render water unsuitable for consumption or other household uses. Animals too, especially mosquito larvæ, present in drinking waters, may play an important rôle in human health. At various times the people of Boston have noticed an odor of cucumbers in their drinking water. However delectable the odor of cucumbers may be in a salad, the inconsistency of human nature is such that Boston people strongly objected to it in their drinking water, the more so as it suggested certain unsavory things such as garbage cans, or a vegetable push cart in Salem Street. Investigation proved however that the



SYNURA

Which imparts the odor of cucumbers to water. From Conn, "Protozoa of Connecticut."

cucumber was entirely blameless in the matter, the guilty party being an innocent looking little animal, the protozoan Synura. Professor Whipple has compiled a list of twenty-two unicellular plants and animals which are responsible for various odors in water, ranging all the way from the delicate perfume of the violet to the disgusting smell of the piggery. Some organisms indeed run the whole gamut of odor, depending on the number present and the amount of decomposition, from the odor of a violet or a geranium to that of a fish, or from the smell of newly cut grass or corn to that of the pig-pen. "Things are not always what they seem." On one occasion seven out of ten people declared that highly diluted kerosene smelled like perfumery, which observation may be interpreted either as a libel on certain "perfumery" or *vice versa*.

When the shirt of your bosom returns to you an hour before dinner stiff and glossy, but with dull brown stains upon it, do not blame the Chinaman or the laundry maid; go rather

to headquarters and call the culprit *Crenothrix* before the bar of outraged private opinion. This is a microscopic filamentous plant allied to the bacteria, which sometimes develops extensively in water pipes and deposits iron in its sheaths, and to which the stains on clothes are sometimes due.

The work of the sanitary biologist in connection with waters for drinking and other domestic uses has been to ascertain the effect of various organisms present in the water, and the means of control and removal of those which are injurious. But it would take us too far afield to go into this subject, which is largely a technical one of sanitary engineering.

The work of the Bureau of Fisheries, being primarily of an economic character, may perhaps best be discussed elsewhere, which leaves us the more purely scientific phases of fresh water biology for consideration here. The problems of the biologist who studies the life of inland waters, are much the same as those of the biologist upon the sea. His work is to ascertain the kinds of life inhabiting these waters and their abundance and behavior in relation to their environment. His first undertaking then is to study the physical and chemical character of inland waters and to determine the species of their animal and plant inhabitants, while secondarily there opens up to him a vast field of questions relative to the structure, nutrition, reproduction and movement of these inhabitants, and the way in which their activities are related to the various factors in their environment. Most of these problems find a place as well in other fields of biology to which reference has been made elsewhere. We may here consider a few which belong especially in this distinctive field.

In the yearly life of lake or river there occurs a cycle of changes even more marked than those of the ocean. During the warm bright months of summer the plants and animals enjoy the heyday of their existence and may multiply so rapidly that the water appears "soupy" from them. Especially is this true of the algæ, which may form a thick green scum on the surface of lake or pool. But with the advent of the cold, when lakes and ponds pass into a period of winter "sleep," the life which they contain seems almost to vanish, so that where in summer one might find a thousand individuals of animal or plant, in winter he may find one or two or even none at all. At this time changes occur in the water which may have a profound (even a life and death) influence in the life of its inhabitants. When a lake is frozen over to a thickness of several feet, and when on top of the ice sheet is laid a blanket of snow, several more feet thick, the

oxygen content of the water may be so reduced as to smother many of its inhabitants. The shores of shallow lakes in the north, after an unusually long, hard winter, may be lined in spring with the decaying bodies of hosts of fish, which have thus perished. For aquatic animals require fresh air as well as those who inhabit terra firma, or rather the oxygen which is dissolved in the water from the air. At least most of them do. Professor Juday at Wisconsin has however recently made the very interesting claim that many species of animals, Protozoa, worms, insect larvæ and even molluscs may inhabit the oxygen-free ooze at the bottom of lakes. While Professor Juday's observation needs confirmation, there is no question that many aquatic animals can live in water with a very low oxygen content. This does not mean however that they are living without oxygen, which is a *sine qua non* for all living things, but merely that they obtain it in some other way, possibly through breaking down oxygen-containing substances in the water, or it may be directly from their food.

Another effect of winter upon shallow lakes is the concentration of dissolved substances in the lower levels. When ice forms on the surface of water, any substances dissolved in the latter are in some mysterious way filtered out of the freezing water and as a result become more concentrated in the unfrozen water, and very much less so in the ice, sea ice containing only about one-fifth as much salt as sea water. This increase in concentration of the salt content of brackish lakes in winter may materially affect the life which they contain, and may even be a crucial factor in determining the presence of various species of animals in the water. In Devils Lake, North Dakota, we have a fine example of one of these shallow, brackish lakes, which are characteristic of much of our western territory. It has a maximum depth of not more than eighteen feet, while much of the lake is so shallow that it freezes solidly in winter. In earlier days when the lake was deeper it abounded in pickerel, and in recent years many efforts have been made to restock it. In many of these experiments fish were kept alive for weeks during the summer, but with one or two possible exceptions no results of these experiments were evident the following spring. The probable explanation of these failures is that the lake had about reached that degree of concentration (14,000 parts of solids in 1,000,000 parts of water) which the experimental fish can stand, and that with a considerable increase in this concentration in winter, due to a three-foot layer of ice, they were unable to survive.

Not alone are dissolved substances separated from freezing

water, but bacteria also suffer a "freeze out," so that ice harvested from sewage-contaminated water may be fit for drinking. Analyses made by the Massachusetts State Board of Health and the North Dakota Public Health Laboratory have shown that clear ice taken from polluted water may contain as low as 1% of the number of bacteria present in the water. This is not true in all cases however as there are many factors influencing the result.

Small bodies of water may undergo other changes than those due to cold and heat, freezing and thawing. Many pools, formed in spring from rain or melting snow, and swarming with life in the early months of summer, dry up completely during late summer or early autumn, with resultant destruction of the life which they contain, except those forms which are able to survive long periods of drouth with consequent extremes of heat and cold.

But in spite of the destruction of life, which occurs in these temporary ponds each year, every succeeding year they are swarming with living things again as though nothing had happened. What has become of this life meanwhile, and how is its cycle maintained in winter when Jack Frost seizes the waters of the North in his icy grasp?

Some aquatic animals and plants can over-winter in their ordinary condition, their rate of increase being merely slowed down temporarily. Many fresh water copepods may be found beneath the ice in winter oftentimes even carrying eggs, and consequently actively reproducing. Fresh water beetles and some other insects live over winter, and the same is true of rotifers, molluscs and other fresh water forms of both plants and animals. There is a case on record of a frog reviving even after being frozen in a solid block of ice. Sir John Franklin records the revival of frogs and fish after freezing, a specimen of carp recovering sufficiently to "leap about with much vigor after it had been frozen thirty-six hours." An Alaskan fish has been reported by one observer to survive freezing for "weeks" and "when thawed out they will be as lively as ever. The pieces (which have been chopped out of a frozen mass with an axe) which are thrown to the ravenous dogs are eagerly swallowed, the animal heat of the dog's stomach thaws the fish out, whereupon its movements cause the dog to vomit it up alive." A Jonah among the fishes!⁵

On the other hand some algæ have been found living in hot springs with a temperature of about 170°F. and some

⁵ The writer would hesitate to accept this story without corroborative evidence. It has been cited however by Eigenmann in Ward & Whipple's "Fresh Water Biology."

bacteria in the spore stage can survive boiling. Some fish even may withstand a temperature of 128°F. Many forms of aquatic life however can apparently only survive the winter as eggs or other resting bodies, which settle to the bottom, there remaining quiescent until the advent of the spring. The eggs of some crustaceans apparently require to be frozen, while others apparently must be dried as well as frozen in order to hatch. Many of them doubtless can survive long periods of drouth and cold. Those of *Estheria* have been hatched after being kept dry for nine years.

Some aquatic animals survive unfavorable conditions by surrounding themselves with a shell or cyst and lying dormant for a time. The deeper waters in some lakes are apparently entirely free from oxygen in summer. At this time Professors Birge and Juday have found in certain Wisconsin lakes a *Cyclops*, which surrounds itself with a gelatinous shell, and goes to sleep until the cooler weather in the fall causes the surface water to gradually settle to the bottom, carrying with it the oxygen which it has absorbed from the air; whereupon, the *Cyclops* wakes up, and throwing off its sleeping jacket, resumes the "strenuous life" once more.

Many crustaceans, rotifers and worms lay two kinds of eggs—a thin-shelled "summer" egg which develops quickly without fertilization, and a thick-shelled "winter" egg, which after fertilization passes the winter at the bottom of pond or pool to hatch in the succeeding spring. Fresh water sponges and Bryozoa form resting bodies known as "statoblasts," which over-winter in a resting condition, resuming active growth in the spring. Flowering aquatic plants such as the ditch grass, the crowfoot or the water-cress, may like land plants, live for either one or more seasons. In the former case the life of the species is continued by seeds or resistant buds, which, like the "winter eggs" of various species of animals, live over winter at the bottom of pool or pond to become active when the face of spring smiles again upon the waters. In plants which live for more than one season much of the plant dies in the fall, leaving mainly the underground parts persisting over winter, from which the aquatic and aerial stems and leaves are renewed the succeeding year. Some plants however such as the hornwort (*Ceratophyllum*) and the water-weed (*Elodea*) may retain their leaves throughout the winter beneath the ice, and aid in furnishing oxygen to support the animal inhabitants of the water. Plants and animals living in temporary pools can only persist through the formation of resting bodies of some sort—seeds, eggs, etc., which can withstand a prolonged period of drying.

Such temporary pools may be restocked, perhaps chiefly from the outside by the action of wind, birds or other agencies.

But not only do inland waters show an annual cycle in their life, dependent on the changing seasons; there may be several cycles, some greater and some less, in the life of lake or pond or river. These cycles depend in large measure upon changes in amount of food-stuffs in the water. They are initiated by the plants upon which the animals are primarily dependent for their food. When the melting snows and rains of spring are washing the surface of the land and draining through the soil into lakes and rivers, they carry with them large quantities of mineral and organic matters in solution; which substances, especially the latter, with their high nitrogen content, furnish abundant food supply for plants, which in turn serve as provender for animals. Rainy periods later in the season may be followed by temporary increase of life in inland waters. Even the phases of the moon are seemingly reflected in the abundance of the plankton, for Professor Kofoid, in his extensive studies on the plankton of the Illinois River, found a series of monthly increases or "pulses" of the plankton, corresponding roughly at least with the periods of full moon, and possibly due to the increase of light at these periods resulting in increased activity of chlorophyl-bearing plants in the water.

The movements of fresh water animals, to which reference has already been made, furnish a fascinating field for study. They display vertical and horizontal migrations similar to those of marine animals. The surface of a lake which may be swarming with animals by night, may be almost depopulated by day. In the cool days of spring and fall the shallow shore waters, readily heated by the sun, may be an attractive haven for animals of many sorts, which in the hot days of midsummer seek the cooler waters farther out from shore. But not only are the movements of animals controlled by evident physical and chemical factors, there appear to be biological factors also which determine them, which is probably only another way of saying physical and chemical factors in a less evident form. But however that may be, fresh water animals often congregate in great swarms, just as do insects, fishes, birds or mammals. One region of a pond may be almost free from some species of animal, while another region only a few feet distant may be so thickly populated as to appear "milky" or "soupy" to the observer. In one such swarm of the crustacean *Moina* the writer has estimated more than 80,000 individuals in a quart of water. The cause of such swarms is as yet unknown.

Such in brief are a few of the methods, discoveries and problems of the aquatic biologist. Since time immemorial men have turned to the water as the source of life, and to-day the study of its life, in spite of difficulties and perplexities, is one of the most compelling fields of human interest.

CHAPTER XV

Economic biology. Dependence of man upon nature. Ignorance of nature the cause of economic loss. Conservation and increase of natural resources.

An ardent French entomologist in Medford, Mass., was one day eagerly inspecting some caterpillars which he had reared from eggs brought by him from Europe, when some of them, growing tired of his society, made their escape and went on their way rejoicing. This was in 1869. From 1890 to 1900 Massachusetts spent about \$1,000,000 to fight the gypsy moth. At this time the pest being partly under control the efforts were relaxed, with the inevitable increase of the pest, and its further spread over a large part of New England and into Canada. At the present time large sums are spent annually by national, state and local agencies for its repression, but in spite of these efforts large areas of forest are denuded every year and the pest is still spreading.

In 1850 caterpillars were devouring the trees of the eastern United States. But in England there was a merry, if not melodious little sparrow, who was supposed to enjoy nothing so much as a meal of luscious juicy caterpillars, and so what was more natural than to bring sparrows from the old world to enjoy the rich feasts of caterpillars provided by the new? But no sooner was the immigrant comfortably established in his new home than he proceeded to follow the injunction which the Creator gave to primitive man—"Be fruitful and multiply and replenish the earth," and today he has spread over virtually all of the United States and much of Canada, and is emulating the example of his fellow countrymen by driving before him many of the native inhabitants and inheriting their patrimony; so that today the English sparrow is one of the few recognized pests among our birds.

Inhabiting the wheat fields of the greater part of the United States is a little fly known as the Hessian fly, about an eighth of an inch long, which lays its eggs on the leaves of the wheat, and whose larvæ as they hatch crawl down the leaves to their base, where they burrow into the stem and kill the plant. This fly is supposed to have come to America as an unintentional ally of King George with his



THE GYPSY MOTH

(Right)—Gypsy moth caterpillars on trunk of tree below band of sticky material. From Burgess, "The Gypsy Moth and the Brown-tail Moth and their Control," Farmers' Bulletin, No. 845.



TREES STRIPPED BY GYPSY MOTH CATERPILLARS
Courtesy of the U. S. Bureau of Entomology.

Hessian soldiers; hence its name. Another immigrant which came to us in Revolutionary days was the brown rat.¹

This rat first crossed the Russian frontier of Asia in 1727 in such numbers that it soon overran Europe, whence it came to America. With the rat came its parasite, the deadly *Trichina*, while more recently the yet more deadly *Bacillus pestis* of the bubonic plague has become established in California, brought in by rats from oriental ports. What a pity we cannot return to Europe with our compliments all of our



FIELD OF ALFALFA

Ruined by meadow mice in the Humboldt Valley, Nevada, 1907.

Courtesy of the U. S. Bureau of Biological Survey.

undesirables, four-legged, as well as two-legged and winged ones as well!

An old Welsh legend tells of the frantic father, who upon returning to his home found his child missing, and the dog which he had left to guard her dripping with blood; and thereupon slew the faithful creature, only to find his child safe and the body of a great wolf which the dog had slain,

¹ There are two other species of naturalized rats in the United States—the black and the roof rats. Both are too few and restricted in distribution to be of much economic importance, being held in subjection by the stronger and fiercer brown rat.

lying nearby. Somewhat akin to his feelings may have been those of the farmer after shooting the hawk which he thought had been preying upon his chickens, only to find in its talons a rat, which was the real culprit. To kill a hawk is, in the minds of most of us, a laudable act, for are not all hawks "hen hawks," the inveterate enemies of the poultryman and of smaller creatures of their own kind? So at least thought the farmers in the Humboldt Valley in Nevada, which in 1907 was visited by a plague of mice, which ate up every-

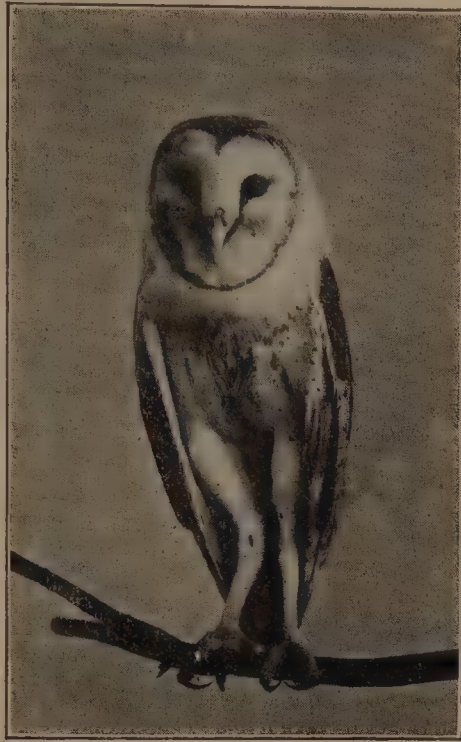


RED-TAILED HAWKS

One of the commoner "hen hawks" of the farmer, from an illustration by Louis Agassiz Fuertes.

Courtesy of the U. S. Bureau of Biological Survey.

thing in sight, gnawing the bark from fruit trees, burrowing in the alfalfa fields and destroying the potatoes and other crops. Out of 20,000 acres of alfalfa, 15,000 were so badly damaged that they had to be ploughed under. At the height of the plague in November, 1907, it was estimated that there were from 8,000 to 12,000 mice to every acre, while the total loss to the valley was estimated at \$300,000. Such mouse plagues are no new occurrence. Numerous outbreaks of these pests have occurred in Europe at various times, their numbers sometimes becoming so great that the simple-minded peasants half believed that they had been rained upon them from the clouds.



THE BARN OWL

Photo by Elwin R. Sanborn.

Courtesy of the New York Zoölogical Society.



A PILE OF SKULLS OF MICE AND RATS

Contained in the pellets disgorged by a family of barn owls. From
Lantz, Farmers' Bulletin, No. 670.

Courtesy of the U. S. Bureau of Biological Survey.

The abundance of the mice in Humboldt Valley attracted hawks in large numbers to feast upon the good things which Nature had so bountifully provided for them. But failing to recognize in the hawks their best ally in their war against the mice, the ignorant residents seized their guns and proceeded to slay their best friends; so that a traveler through the valley observed twenty-nine of these birds hanging on the fences.

So too thought the legislature of Pennsylvania when in 1895 they passed the notorious "scalp act," providing for a bounty of fifty cents for every hawk or owl killed within the state, as a result of which half-baked legislation more than 100,000 valuable birds were killed, at an expense of nearly \$100,000 to the state for bounties and notary fees, and an estimated loss of more than \$4,000,000 from the increase of harmful rodents resulting from the destruction of their enemies, the hawks and owls. And yet all this in the short space of a year and a half. Fortunately the legislature soon recovered its equilibrium and the law was repealed.

But how do we know that the hawks and owls, or at least most of them, are the farmer's friends rather than his enemies? A few specific facts will best answer this query.

Hawks and owls have a habit of throwing up the undigested parts of their food in the form of pellets containing the hair, bones, feathers, etc., of their prey. For many years a pair of barn owls were wont to nest in the tower of the Smithsonian Institution in Washington. An examination of two hundred pellets found beneath their nesting site revealed 454 skulls, of which 412 were those of mice, 20 of rats, 20 of shrews, one of a mole, while only one was that of a bird (sparrow).

In the "Pacific Rural Press" for Oct. 23, 1897, is an account of a pair of these same birds nesting in a pigeon house, whose owner, supposing that they were feasting on his pigeons, shot the male and trapped the female. Upon examining the nest he found ten young "gophers" (ground squirrels?) in it, whereupon he promptly released the female.

Of 146 stomachs of the great-horned owl examined, only 31 contained poultry and 8 other birds, the remainder containing various mammals, insects and miscellany.

An examination of 562 stomachs of the red-tailed hawk showed remains of poultry or game birds in 54, other birds in 51, mice in 278, other mammals in 131, insects in 47, miscellany in 59, and nothing in 89.

It was primarily to answer questions such as these that the U. S. Biological Survey was organized in 1885, becoming

a bureau of the Department of Agriculture some twenty years later. This bureau has contributed more to our knowledge, both scientific and economic, of the birds and mammals of North America than any other agency. We cannot in so brief a compass do justice to its work, but a bird's eye glance at it may be of interest. At the outset it must be admitted that, like a lusty youngster, the Bureau has frequently outgrown its clothes, and frequently also has it wandered far from its parental home. In how far the hair-splitting refinements in the classification of birds and mammals in which it has often indulged itself may be of value either to science or agriculture is open to question, but there can be no question of the value both to science and agriculture of the great bulk of its work. The vast amount of data which it has gathered relative to the classification and distribution of North American birds and mammals are indispensable to any study of the influence of environment upon their evolution and spread, while its studies on the migration of birds have furnished invaluable data not only for the study of the causes of this as yet inexplicable phenomenon, but also for the formulation of laws for their protection.

Prior to the establishment of the Bureau our knowledge of the food habits of birds was the result of a few sporadic investigations. Since its inception it has conducted a systematic study of this question, including the examination of some 80,000 stomachs of many species of birds, as a result of which we now have very definite information regarding the economic value of most of our wild birds, and can pursue a rational program for their protection. Many instances of the value of birds to the farmer which have been shown by these investigations could be cited, in addition to those already given of the food habits of hawks and owls. One of the worst foes of the horticulturist, especially the fruit grower of California, is the scale insect. This, as its name implies, is a tiny scale-like creature of no resemblance externally to an insect, but containing evidence of its relationship in its internal structure and its development. I have no data relative to losses from scale insects, but an estimate of a cost of 10 to 25 cents a tree as a protective tax against the San José scale, gives some idea of the burden they put upon the fruit grower. We shall have more to say regarding these insects later on, but for the present we note that the Bureau has shown, what was formerly unknown, that many species of birds prey upon them, while of some species they form the favorite food.

The habitué of field and forest, who seeks his favorite haunts after the first snow fall of the winter, is likely to encounter

companies of little birds, who, in spite of winter and its snow, are busily engaged in reaping the plentiful harvest of the weeds. Flitting from stem to stem, they pick out the seeds from their shells, while others follow in their wake to pick up the gleanings from the snow. The late Dr. Judd of the Survey, in his studies of the food habits of sparrows, examined a piece of ground eighteen inches square in a patch of smartweed where several species of sparrows had been feeding. On this patch he counted "1130 half seeds and only 2 whole seeds. During the ensuing season no smartweed grew where the sparrows had caused this extensive destruction."² It has been estimated that in Iowa alone a single species, the tree sparrow, destroys in one year 875 tons of weed seed, and that in the United States as a whole the different species of native sparrows, numbering more than one hundred, save \$35,000,000 for the farmers every year.

Heretofore the protection of our birds has been more or less of a hit or miss undertaking, principally the latter. While the birds might be fairly well protected in one state, they received little or no protection in another. Realizing these inequalities and injustices in our local laws, the Survey, aided by bird lovers throughout the country, drew up and put through Congress in 1913 the migratory bird law, which gives the nation control of all migrating birds within its domain. By this act all such are afforded uniform protection throughout the United States, and while the law is imperfect in itself and as yet inadequately enforced, its results even so have been very gratifying. Especially is this true of game birds. Previous to the passage of this law the shooting of game birds during the spring migration, when the birds were en route to their breeding grounds, and in many instances had actually begun to breed, was permitted by some states. With the abolition of the spring shooting has come a notable increase of the birds in the fall, which is the legitimate time for hunting. In 1916 a treaty was drawn up between the United States and Canada, providing for the protection of migrating birds between the two countries. This treaty has recently been made effective through the passage of the necessary legislation by both countries. The Lacey Act, passed in 1900, which controls the shipment of game from one state to another, and has been an efficient check to the pot hunter who ships his game to large cities for market, is another outcome of the Survey's efforts to protect our wild birds and mammals.

² Judd, "The Relation of Sparrows to Agriculture," Biol. Survey, Bull. 15.

But the protection of the farmer's friends is only one of the Bureau's manifold activities. Many a wild creature is the farmer's inveterate enemy and does untold damage to his cattle or his crops. With the drain on the world's resources caused by the great war and its aftermath of anarchy and ruin, and the ever-mounting cost of existence, it behooves us to close up every leak where natural wealth is wasted. Within the borders of our country today, we are harboring a host of parasites, who are "eating us out of house and home." On our western ranges we are feeding our wolves and coyotes \$20,000,000 worth of stock every year; to ground squirrels, mice and other rodents we contribute \$150,000,000 worth of food crops, while the brown rat levies an additional toll of \$200,000,000. These figures perchance sound excessive. Let us analyze them a little closer.

"As an indication of the losses due to predatory animals it may be stated that the chairman of the State Live Stock Board of Utah estimates an annual loss in that region amounting to 500,000 sheep and 4,000,000 pounds of wool. The president of the New Mexico College of Agriculture, as a result of a survey of conditions in that state, estimates an annual loss there of 3 per cent of the cattle, or 34,000 head, and 165,000 sheep. A single wolf killed by one of the Bureau hunters in southern New Mexico was reported by stock owners of that vicinity to have killed during the preceding six months 150 head of cattle valued at not less than \$5,000. In July, 1917, two male wolves were killed in Wyoming which in May had destroyed 150 sheep and 7 colts. Another pair of wolves killed near Opal, Wyoming, were reported to have killed about \$4,000 worth of stock a year. Another Wyoming wolf, trapped in June, 1918, had killed 30 cattle during the spring."³

"In the Arnold Arboretum, Jamaica Plains, Mass., during the winter of 1903-4, meadow mice destroyed thousands of trees and shrubs, including apple, maple, sumac, barberry, buckthorn, dwarf cherry, snowball, bush honeysuckle, juniper, blueberry, dogwood, beech, and larch. Plants in nursery beds and acorns and cuttings in boxes especially were harmed. . . . During the winter of 1905-6 a small orchard of apple and pear trees near Washington, D. C., was under observation from October to April. Attacks by meadow mice began in the early fall, possibly in August. They were continued during every succeeding month, being greatest during two short periods of snow. . . . Adjoining the orchard was a tangled thicket on low, moist ground, in which meadow mice were abundant.

³ Report of Chief of Bureau of Biological Survey, 1918, p. 3.

"On March 16, 1906, I found that of 380 apple trees, 164, or over 43 per cent, were ruined, being completely girdled, some to a height of 8 to 10 inches above the ground. Thirty-six others, nearly 10 per cent, were less badly injured, while 180, or 47 per cent, apparently, were uninjured. Of 200 pear trees in the orchard 50 were more or less seriously damaged. The injury to these was inflicted early in the fall. . . .

"In December, 1903, I examined a large orchard in Marion



MEADOW MICE

A great pest which sometimes become so numerous as to form veritable plagues. From an illustration by Morita.

Courtesy of the U. S. Bureau of Biological Survey.

County, Kan., where field mice were causing much damage. . . . The orchard comprised 480 acres and contained about 26,000 trees, mostly apple, eight to ten years transplanted. The trees averaged about 4 inches in diameter, but many measured 5 or 6 inches. The majority were headed low, their outer drooping branches touching the ground. In the spring of 1903 corn had been planted by listing it in the open spaces between the rows of trees; but owing to an unusually wet summer, the crop had been abandoned, and sunflowers and other weeds and grasses had made a luxuriant growth throughout the orchard. Over much of the area, apparently, no attempt

had been made to cut down the weeds; and where they had been mowed they had been raked into piles and not burned or removed.

"In this neglected orchard field mice—the prairie vole—had found a congenial home. Already abundant in 1902, they bred plentifully in the open fall of that year and in the early warm spring of 1903. The ensuing moist summer also was favorable for continued reproduction, and by the fall of 1903 they were present in hordes. All the orchards of the neighborhood—a comparatively level upland prairie—had



APPLE TREE GIRDLED BY MEADOW MICE
Courtesy of the U. S. Bureau of Biological Survey.

been neglected and all were invaded by mice; but the one above mentioned was the largest and most neglected, and therefore it suffered most severely. By December 18, the date of my first visit, mice had wholly or partially girdled at the surface of the ground fully 5,000 apple trees and had denuded of bark many of the low branches. The owners of the orchard, thinking that none of the trees could survive the injuries, then estimated their loss at from \$25,000 to \$30,000.

"Examination showed that the ground everywhere was honeycombed by mouse burrows and tunnels to a depth of 3 or 4 inches, and that the surface was almost covered by ■

network of runways of the prairie vole. Upon digging into the burrows at the base of apple trees, I found many twigs, 4 to 6 inches long, that had been entirely stripped of bark and left lying in little piles. I had no difficulty in finding where the twigs had been severed from low-growing branches and the tips of sprouts, and in distinguishing, by the smaller tooth marks, the cutting done by mice from that done by rabbits. Whether the twigs had been first stored and afterwards fed upon in cold weather, I was unable to determine, for I found none with bark remaining upon them. Probably they were carried to the burrows merely for leisurely but immediate consumption.

"Contrary to the usual habits of voles in our Northern States, this injury had been done during mild weather. Up to December 18 the season had been very warm and open. No snow lay on the ground for more than twenty-four hours. Ordinary food, such as grass, seeds, and grain, was abundant, so that the only explanation for the injury to trees seems to be the vast numbers of voles present and their preference for a partial diet of bark.

"Voles, however, were not the only animals abundant in the orchard. Rabbits, both cottontails and jacks, were there in great numbers, and already had begun to eat the bark on the trunks of some of the trees and on the low limbs, and to cut the tips of branches and sprouts within their reach. Later, when cold weather set in and snow covered the ground, they also seriously damaged the trees."⁴

"Experiments show that the average quantity of grain consumed by a full-grown rat is fully 2 ounces daily. A half-grown rat eats about as much as an adult. Fed on grain, a rat eats 45 to 50 pounds a year, worth about 60 cents if wheat, or \$1.80 if oatmeal. Fed on beefsteaks worth 25 cents a pound, or on young chicks or squabs with a much higher prospective value, the cost of maintaining a rat is proportionately increased. Granted that more than half the food of our rats is waste, the average cost of keeping one rat is still upward of 25 cents a year.

"If an accurate census of the rats of the United States were possible, a reasonably correct calculation of the minimum cost of feeding them could be made from the above data. If the number of rats supported by the people throughout the United States were equal to the number of domestic animals on the farms—horses, cattle, sheep, and hogs—the minimum cost of feeding them on grain would be upward of \$100,000,000 a year. To some such enormous total every farmer,

⁴Lantz, "An Economic Study of Field Mice." Biol. Survey, Bull. 31, pp. 25-9.

and indeed every householder who has rats upon his premises, contributed a share.⁵

“(Corn) suffers greater injury from rats than any other crop in the United States. Besides depredations on newly sown seed, the animals attack the growing grain when in the milk stage. They climb the upright stalks and often strip the cobs clean of grain. The writer has seen whole fields of corn so destroyed and in many cases has observed parts of fields amounting to several acres practically ruined. A writer in the “American Agriculturist” reported an instance in which



THE COTTONTAIL RABBIT IN ITS FORM

From Lantz, “Cottontail Rabbits in Relation to Trees and Farm Crops,” Farmers’ Bulletin, No. 702.

Courtesy of the U. S. Bureau of Biological Survey.

rats destroyed three-fourths of the corn on 13 acres of land. In 1905 a large portion of the crop grown on the Potomac flats near Washington was destroyed by rats. . . . A farmer living near Grand River, Iowa, relates the following experience:

“We had about 2,000 bushels of corn in 3 cribs to which rats ran, and they ate and destroyed about one-fourth of the corn. Much of it was too dirty to put through the grinder until it had been cleaned an ear at a time. All the time we were poisoning and trapping the rats. We killed as high as 300 rats in two days and could hardly miss them. They de-

⁵At the present time these figures would be considerably greater.

stroyed more than enough corn to pay taxes on 400 acres of land.'

"The destruction of feed stuffs by rats is a serious loss not only on the farm but in almost every city and village in the whole country. Often through carelessness or the indifference of servants, the bin or barrel in which feed is kept is left uncovered, and rats fairly swarm to the nightly feast. In some cases investigated in Washington, D. C., the loss was equal to 5 or 10 per cent of the grain bought. A grocer was buying feed for two horses and several hundred rats; the horses were fed at regular intervals, the rats nearly all the time. In the cases of establishments keeping from fifty to a hundred horses, the loss of feed in the course of a year often amounts to a large item.

"Rats destroy also many eggs both on farms and in cities. Fresh as well as incubated eggs are eaten by these rodents. Commission men and grocers complain much of depredations upon packed eggs. Those at the top of a case are broken by these animals, and parts of the yolks run down and stain the unbroken ones. Often, however, rats carry away eggs without breaking them, and display much ingenuity in getting them over obstacles, as up or down a stairway. On a level surface the rat rolls the egg before him, but he can easily carry it between a paw and his neck and chin, while going upon three legs.

"A commission merchant in Washington relates that he once stored in his warehouse 100 dozen eggs in a wooden tub with a lid of boards nailed on. Rats gnawed a hole through the tub at the top and carried away all but 28½ dozen, leaving no shells or stains to show that any had been broken. . . .

"Rats are very destructive to tame pigeons, attacking especially young squabs, but destroying eggs, also. They often show great cunning in finding entrances to the cages. A fancier residing in Washington, D. C., missed many of his squabs and was satisfied that the only opening by which an animal could enter was the exit at the top of the flying cage. He closed the opening and set a trap there, in which he caught a large rat. The animal had climbed the wire netting on the outside and descended it on the inside to reach the pigeons." ■

And all these like so many other losses, are largely the result of ignorance or carelessness.

Not only are these destroyers living at our expense, but many of them are repaying our indulgence by spreading disease among man and beast. We shall see elsewhere how the rat, and to a lesser extent, the ground squirrel in California are a constant menace to our health, while in many of the

° Lantz, "The Brown Rat in the United States," pp. 18-23.

western states, the wolf and coyote are spreading rabies among our stock and thus indirectly endangering human life itself. One of the most important activities of the Bureau at the present time is the destruction of these noxious animals. It keeps a force of about three hundred men in the field trapping, shooting and poisoning predatory animals, mainly



THE COMMON RAT

Whose board bill is costing us in the neighborhood of \$200,000,000 annually. From a drawing by E. R. Kalmbach.

Courtesy of the U. S. Bureau of Biological Survey.

wolves, coyotes, wild cats, and to a lesser extent, bears and mountain lions. Definite results are difficult to show as a result of this campaign, but a very marked reduction in stock losses has been noted in those regions where it has been consistently carried on.

Let us turn aside for a moment and follow one of the Survey's hunters on his lonely way as he pursues the big gray

wolf of our western plains. Whether these animals are intelligent or not we shall leave to the psychologists to decide, if they can; their actions in any event certainly appear so. The wolf is a highly picturesque and interesting outlaw. His teeth are turned "against every man and every man's hand against him." With every sense rendered keen by the sharpness of his struggle for existence he has become on the one hand a most skillful thief, and on the other a most elusive criminal. The most tempting bait will not decoy him into a trap, while the least scent of man is a warning of danger. The trapper as he goes afield soon strikes some cattle path or trail, winding in and out among the hills. He follows this until he finds two bushes growing a few inches apart. Between these he makes a little hole in which he sets his trap and firmly fixes it to a sunken stake or heavy stone. Upon the trap he lays a sheet of paper which is well covered with fine earth and bits of sticks or leaves or straw, causing the surface of the ground over the trap to appear as natural as possible. Over all a little water is sprinkled and nearby a few drops of wolf perfume or scent. Now a wolf's notions as to perfume are not exactly in accordance with our own. A very choice preparation for a wolf is prepared by allowing a chunk of raw meat to rot until it "smells to Heaven." To this is added some animal oil such as sperm or lard oil and then a little musk or beaver castor. In preparing the trap great care must be taken to avoid leaving any trace of human scent. This is prevented by wearing old, well scented gloves and covering the shoes with scent.

Or the trapper finds beneath some overhanging ledge of rock, high on the slope of a barren hill, tracks it may be leading to a den, or the bones of some unfortunate victim, and digging out the den a family of puppies is discovered and their earthly career is quickly ended. Or the freshly killed carcass of beef or sheep is found, which is poisoned with strychnin and when the wolf returns for a second meal, this meal becomes his last.

The war on prairie dogs, ground squirrels, pocket gophers and other rodents is largely conducted with poisoned grain. A few kernels of grain poisoned with strychnin placed in a burrow will effectually dispose of the occupants in short order.

"As an illustration of the effectiveness and economy of the methods of destroying these pests, a badly infested plot of 320 acres was chosen for a demonstration in northern Arizona. One man spent a day distributing poison over this area, at a total cost for labor and material of \$9.79. The following day 1,641 dead prairie-dogs were picked up from



GRAY WOLF AND PUPS
Killed by one of the government hunters.



ONE OF THE MANY SPECIES OF GROUND SQUIRRELS
Against which the government is now waging an active campaign.
Courtesy of the U. S. Bureau of Biological Survey.

this tract. With the number which must have died in their holes, there can be little question that more than 2,000 prairie-dogs were destroyed in this experiment.

"More than 3,500,000 acres of Government land have been practically freed from these pests."⁷

One of the worst poachers in the West is the jack rabbit, which one may occasionally see from the railway, loping leisurely across the prairie, or sitting up on his haunches to gaze with fearless curiosity at the passing train. Besides helping himself liberally to the farmer's grain and hay, he varies his diet now and then by nibbling a circular strip of bark from the fruit trees, "girdling" and thereby killing them. A favorite pastime in the Southwest has been the rabbit drive. On a given day a troop of boys and men with dogs and horses form a line about a given area and then riding to



THE POCKET GOPHER

One of our numerous mammal pests. From an illustration by E. T. Seton.

Courtesy of the U. S. Bureau of Biological Survey.

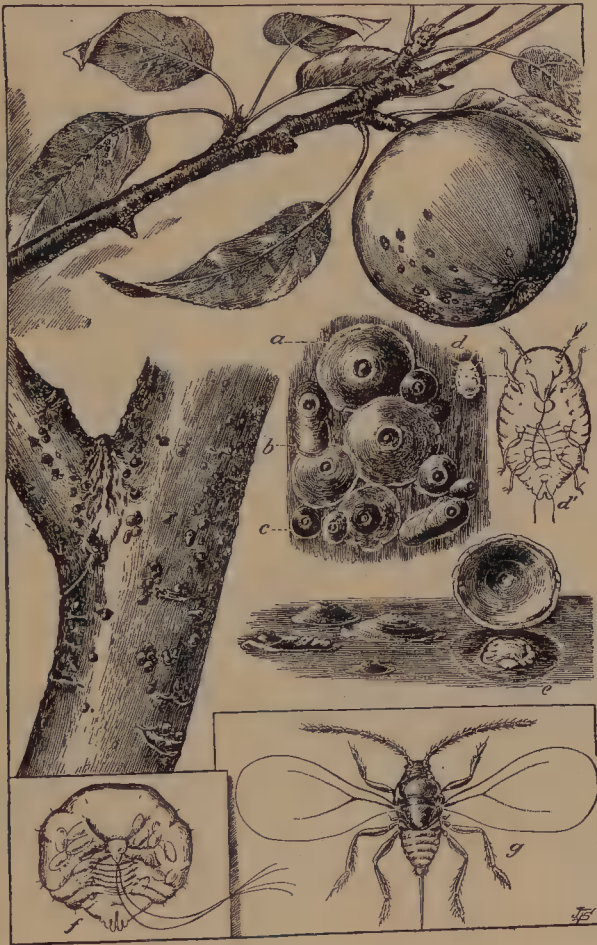
and fro, with the aid of the dogs, proceed to "beat up" the doomed rabbits, and gradually converging, drive them toward the town where the residents are waiting to receive them, not with open arms, but with clubs and shot guns. In this way, not only is the neighborhood rid of a host of pests, but a large supply of meat is provided.

The trap is also an effective weapon in the campaign against the furry pests of field and orchard.

Through the watchful activity of the Bureau it is probable that many another catastrophe similar to the introduction of the English sparrow, gypsy moth, and Hessian fly has been averted. Some years ago the mongoose applied for admission to the United States, and a few individuals did in fact gain an entrance. The mongoose has been called the "cat of Pharaoh" and strangely enough it has also been named "Pharaoh's mouse." It is a traditional enemy of serpents and "according to Aristotle and Pliny (it) first coats its body

⁷ Report of Chief of Bureau of Biological Survey, 1918, p. 4.

with a coating of mud, in which it wallows, and then with this armour can defy the serpent. Topsell tells the tale better. The Ichneumon burrows in the sand, and 'when the aspe espyeth her threatening rage, presently turning about



SAN JOSÉ SCALE

a, Adult female scale; b, male scale; c, young scales; d, larva just hatched; d', same, much enlarged; e, scale removed, showing body of female beneath; f, body of female insect, more enlarged; g, adult male of the San José scale. From Quaintance, "The San José Scale and its Control," Farmers' Bulletin, No. 650.

Courtesy of the U. S. Bureau of Entomology.

her taile, provoketh the ichneumon to combate, and with an open mouth and lofty head doth enter the list, to her owne perdition. For the ichneumon being nothing afraid of this great bravado, receiveth the encounter, and taking the head of the aspe in his mouth biteth that off to prevent the cast-

ing out of her poison.' In the West Indies the animal has been described as fearlessly attacking the deadly Fer de Lance and receiving its bites with impunity; it is also added that it will eat the leaves of a particular plant as an antidote! The real explanation of the result of these encounters is of course the agility of the Ichneumon."⁸

The mongoose preys on mice and rats, but unfortunately attacks poultry and wild birds as well. It has been introduced into Jamaica where it has proven a nuisance through



MASS OF SAN JOSÉ SCALES ON TREE TRUNK X 30

From Quaintance, "The San José Scale and its Control," Farmers' Bulletin, No. 650.

Courtesy of the U. S. Bureau of Entomology.

its depredations. By the passage of a law placing the importation of foreign animals under the control of the Secretary of Agriculture, the Bureau has been able to prevent its establishment in the United States.

Monstrous as is the tax which we pay to our four-footed foes, it is small in comparison with the tribute levied by our winged enemies. Estimates of so uncertain a sum as the loss caused by insects are bound to vary, but even accepting the

⁸"Cambridge Natural History," Mammalia, p. 409. By permission of the Macmillan Company.

minimum figure of \$1,000,000,000 annually, the amount is surely ample. Early awake to the danger from insect pests Congress in 1854 appointed an entomologist, whose work was at first conducted under direction of the Commissioner of Patents, but upon the organization of the Department of Agriculture in 1889 was embodied in the Division, now the Bureau of Entomology.



APPLES INFESTED WITH SAN JOSÉ SCALE

From Quaintance, "The San José Scale and its Control," Farmers' Bulletin, No. 650.

Courtesy of the U. S. Bureau of Entomology.

In the eighties the orange and lemon groves of California were threatened with ruin by the innocent looking, but destructive scale insect,⁹ to which we have already referred. Soon the Bureau of Entomology had experts on the ground learning all they could about the vicious stranger. In the course of their studies they learned that the scale insects were natives of Australia, whence they had been imported into California on young orange trees in 1868. Now it occurred

⁹ The fluted scale.

to them that in the native home of the scale might perchance be found some natural enemy, which if introduced into California might drive out, or at least hold in check the terrible scale. And so one of them journeyed to Australia and there he found the ladybird beetle, *Vedalia*, which preyed upon the scale. And this he brought back with him to California,



THE PITIFUL LADYBIRD

a, Beetle; b, larva; c, pupa; d, blossom end of pear, showing scales with larvæ of ladybird feeding on them, and pupæ of ladybird attached within the calyx. From Quaintance, "The San José Scale and its Control," Farmers' Bulletin, No. 650.

Courtesy of the U. S. Bureau of Entomology.

where it thrives; and making war upon the scale it has ever since held it in check, delivering the orange and the lemon from their threatened destruction.

Similar attempts have been made for several years in the war on the brown-tail and gypsy moths, which are so destructive to fruit and shade trees in New England, and while the results have been less spectacular than in the case of the

scale insects, the prospects for the ultimate control of these pests in this way are promising.

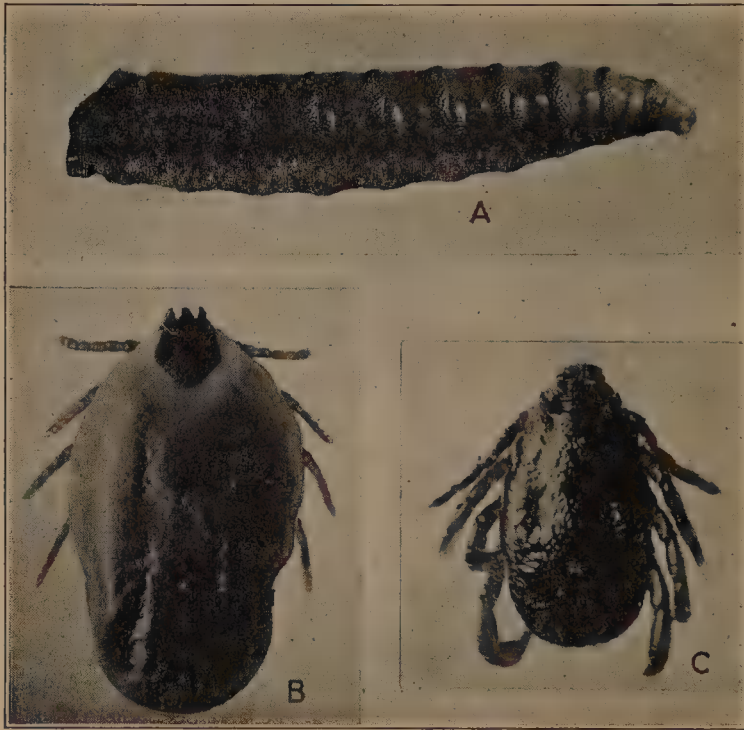
In Hawaii the ravages of the sugar-cane weevil, which bores its destructive way into the sugar canes, have been materially reduced by the introduction of a parasitic fly from British New Guinea. Another dread enemy of the Hawaiian sugar planter is a little bug known as a "leaf hopper," which was probably introduced from Australia about 1898. Soon it was doing so much damage that the production of one large plantation fell from 10,954 tons in 1904 to 826 tons in 1906. Meantime however the expert entomologists were on the trail of the leaf hopper, pursuing it with parasites, furnished by Australia. Their first attempts were failures, but these were shortly followed by success. The parasites thrived and soon had the pest so well under control that this same plantation yielded in 1907 11,630 tons of sugar.

But the path of the experimental entomologist is by no means always strewn with roses. There is in Europe a fly which parasitizes the caterpillar of the brown-tail moth, which is covered with poisonous hairs. These hairs are sufficiently poisonous to produce a serious eruption in man known as the "brown-tail rash." Now there is in this country a variety of the same species of parasite, which does not attack the brown-tail's larva because apparently it is susceptible to the poison of the latter's hairs. Upon the discovery of these facts, the European race was imported into the United States in large numbers, and in the following year was found to be attacking the caterpillars of the brown-tail moth. The enthusiasm of the entomologists aroused by this discovery was short lived however, for the next year none of the caterpillars was attacked. The explanation of this unfortunate state of affairs proved to be that the foreigners were interbreeding with the natives, and their offspring had lost the immunity enjoyed by their European cousins.

In 1796 an epidemic broke out among Pennsylvania cattle, which was traced to a herd from South Carolina which although healthy themselves were infectious to other animals. In 1868 Texas cattle shipped into Illinois and Indiana brought disease into these states causing such extensive ravages that the eastern states became alarmed, not only because of the loss to stockmen themselves, but because of dreaded injury to human health from the consumption of diseased meat.

The cause of all this trouble is a protozoan, parasitic in the blood of cattle, where it produces a disease somewhat similar to malaria in man; while the disseminator of infection is the cattle tick, the life history of which is briefly as follows. After gorging itself upon the blood of its unfortunate vic-

tim, the fertilized female drops to the ground, and deposits on the average about 2,000 shiny brown eggs about $1/50$ inch in diameter. These hatch in about three weeks in summer, while in winter incubation may require nearly six months. After hatching the young tick becomes ambitious, crawling up blades of grass, stems, or posts and there waiting like Mr. Micawber "for something to turn up." Meantime it keeps its forelegs waving to and fro ready to grasp the



“SCREW WORM” AND CATTLE TICK

A—A “screw worm,” the larva of a fly, so-called from the rings of spines about the body.

C and B—Cattle ticks before and after feeding.

Courtesy of the U. S. Bureau of Entomology.

hair of the first animal which comes its way. It may thus patiently await its victim for more than five months, under favorable conditions, but the victim failing to arrive it finally dies. If an unlucky steer comes its way it grasps its hair and crawling up attaches itself to the skin. Here it molts twice, is fertilized, gorged with blood, and drops to the ground to repeat the vicious cycle.

By careful quarantine measures and the treatment of tick-infected cattle with an arsenical dip the Department of Agriculture has freed some 500,000 square miles of the quarantined area in the southern states from a pest, which at one time was estimated to cost the nation from \$40,000,000 to \$100,000,000 annually. For the cattle tick not only does vast damage by transmission of disease, but as a blood-sucker levies a tremendous toll upon the cattleman. It has been estimated that as much as 200 pounds of blood may be lost by an animal in a single season, while in the case of the horse tick, as much as fourteen pounds of ticks have been dropped from one animal in three days, and probably as much more was still attached. But further, the tick has a companion in villainy, for in the sores which it makes the screw-worm fly deposits its eggs, from which the larvæ burrow into the body of the unfortunate victim.

Our knowledge of the fly and the mosquito, upon which the campaign against these pests has been based, is largely due to the work of the Bureau of Entomology.

But space will not permit further discussion of our progress in wealth, health and happiness, due to the work of the economic entomologist.

The work of ridding the South of the cattle tick is in charge of the Bureau of Animal Industry in the Department of Agriculture, whose duty also it is to wage increasing warfare upon the animal diseases which are a constant menace to the nation's supply of meat, leather and other animal products. Scab mites, which in years past levied a heavy toll upon the cattle grower, have been nearly exterminated; the foot and mouth disease, which in 1914 was epidemic in twenty-two states, and was seriously threatening the live stock industry of the country, was stamped out after a hard fight; hog cholera, ever a serious drain upon the hog industry, is gradually being brought under control by the use of a serum and other measures, and an active campaign is now under way for the suppression of tuberculosis in hogs and cattle, a disease serious not alone to the animal industry, but, when present in dairy cattle, a very probable menace to human life itself. The work of the Bureau in safeguarding our meat supply is mentioned in another chapter.

In addition to its campaign against diseases both animal and human, the Bureau is also actively engaged in the increase and improvement of our supplies of meat, milk and other animal products, but details concerning this work would carry us too far afield.

But the economic biologist is concerned not alone with holding fast that which he hath. His duty it is likewise to

seek "fresh fields to conquer" and to lay new tributes upon the altar of commerce. The earliest record of the importation of animals of commercial importance from one country to another is the story of the Chinese princess, who, defying imperial edicts for love of her betrothed, brought some eggs



THE QUARTER-ACRE BAMBOO GROVE AT THE C. J. EDWARDS PLACE
Near Abbeville, Louisiana. Planted in 1898, in 1915 it produced
over 200 large shoots.

Courtesy of the U. S. Bureau of Plant Industry.

of the silkworm over the mountains to her Indian lover, while in the days of Justinian silkworms were brought to Constantinople by Persian priests, who concealed the eggs of the moth in hollow canes.

America is a great experiment station for the breeding of new animals and plants, where the "stranger within our

gates," whether man or beast or flower, is given the best opportunity for making the most of himself. When we think of our immigrants solely in terms of petticoats and pantaloons we should not overlook the fact that many of them are clad in furs or feathers or in the raiment of the lilies, and among these immigrants we find not only the English sparrow and the rat, the pugilists and sneak thieves of the lower strata of animal society, but the ring-necked pheasant



THE UDO

Thrives in the eastern United States and California. The blanched shoots make a very delicious salad vegetable. Introduced by the U. S. Department of Agriculture from Japan, where it is a very popular article of food.

Courtesy of the U. S. Bureau of Plant Industry.

and the reindeer, the aristocrats of the animal world; while if Russia has contributed her thistles as well as her anarchists to our society, no less has she given us her alfalfa and her fruits, as well as her musicians and her scholars.

With the inrush of the eager throngs of Europe and of Asia to our shores, with our rapidly growing population, and occupation of our public domain; it behooves us to "take thought for the morrow" in order that we may have the wherewithal to feed and clothe and shelter our future hordes. So Uncle Sam, ever mindful of the welfare of his children,

has established among his many agencies for this purpose, the Office of Foreign Seed and Plant Introduction of the Bureau of Plant Industry in the Department of Agriculture, whose duty it is to go into the "uttermost parts of the earth" and bring back to us its treasures. From the Asian steppes to the jungles of the tropics its explorers have gone, and from the fertile isles of Japan to the deserts of Arabia, in their search for the useful and the beautiful, to enrich our fields and adorn our dwellings.



A SINGLE CROWN OF THE UDO AFTER BLANCHING
Courtesy of the U. S. Bureau of Plant Industry.

To even name, let alone describe all the manifold varieties of plants whose introduction the Office has attempted, would be out of the question in these pages, but a few of them may be mentioned.

We are accustomed to think of the bamboo in terms of wicker work or fishing rods, but how many of us realize that the young bamboo shoots, which grow at the rate of a foot a day, are succulent and may be eaten like asparagus tips, while the seeds of some species may be used as grain, and the fruits of others cooked and eaten? How often do we think of the

bamboo as serving such varied uses as pulp for paper, masts for vessels, pipes for water and timber for buildings? Says Mr. David Fairchild, in charge of the plant introduction work for the Bureau of Plant Industry: "... there is no plant in the world which is put to so many uses as the bamboo, and



THE TUNG OIL TREE

One of the many valuable plant immigrants introduced into the United States by the U. S. Bureau of Plant Industry.

Courtesy of the Bureau.

in the regions where it grows it is apparently the most indispensable of all plants." Strange as it may seem, the bamboo is not a tree in the ordinary sense of the word, but a grass, the rings on the stem marking the points of insertion of the leaves.

About twenty years ago Mr. William Tevis of San Francisco bought a specimen of the giant Japanese bamboo from

a Japanese nurseryman, which he planted in Bakersfield, and from which in a few years sprang a beautiful grove of trees over fifty feet in height. Several species of bamboo have been introduced into California, while in Florida and other southern states are bamboo groves planted by the Bureau in its experimental gardens.

In the markets of Japan are for sale the stalks of the udo which is used by the Japanese and foreign residents as we



BRANCH OF THE TUNG OIL TREE

The large kernels inside these fruits form the wood oil nuts from which one of the most valuable drying oils known is extracted. These trees will grow in the Gulf States.

Courtesy of the U. S. Bureau of Plant Industry.

use asparagus, but the udo has the advantage of the asparagus, in that its stalks, which are often two feet long and over an inch in diameter at the base, are completely edible, instead of the tips alone as is the case with the asparagus. It is a hardy plant and can probably be raised throughout the United States, though at present it is raised chiefly in the Sacramento Valley. The udo was introduced into the United States by Fairchild and Barbour Lathrop of Chicago in 1903.

Those of us who have enjoyed the delightful hospitality of

the South, may have been victims of a little practical joke on the part of our friends, when we accepted from them a fruit somewhat resembling a plum or large cherry of a yellowish or pinkish color, which made our mouths water in anticipation and pucker in realization. But the Japanese long ago learned how to take the pucker out of persimmon by packing it in barrels saturated with sake or Japanese "booze," and experts of the Bureau of Chemistry have found a means of similarly de-puckering the persimmon with carbon dioxide. But this process is unnecessary with a new variety of Chi-



A VIEW OF THE AVENUE OF PISTACHE TREES

At the Plant Introduction Station at Chico, California. In the autumn the leaves of this Chinese pistache turn a beautiful scarlet.

Courtesy of the U. S. Bureau of Plant Industry.

nese persimmon found in the valley of the Ming Tombs west of Peking, by Mr. Frank Meyer, one of the plant explorers of the Bureau, who has traveled extensively in China, whence he has sent us some 2,500 new varieties of plants. The Japanese persimmon has also been introduced, and is thriving at many points in our southern states.

The tung oil tree of the orient, from the seeds of which is obtained one of the best drying oils known, the importation of which in 1911 amounted to \$3,000,000, has been introduced into California and the Gulf States, where it appears to be thriving; while the pistache tree, a native of central western Asia, is doing nicely in California, so that in the near

future it may not be necessary for us to go to the Asiatics for flavoring for our pistache ice cream. Yet another find in China is a chestnut tree, which is to a considerable extent resistant to the chestnut bark disease which has been playing such havoc in our chestnut groves in recent years, and which may some day replace our vanishing native species.



AN INDIAN MANGO GROWING IN FLORIDA
Courtesy of the U. S. Bureau of Plant Industry.

Into southern Florida, California, Porto Rico, Hawaii, and the West Indies has come the East Indian mango, a fruit long held sacred by the people of this teeming land. In India it is very prolific, some trees bearing between \$100 and \$200 worth of fruit, even at the low rate for which the fruit sells in that country.⁹ The mango is described in Bai-

⁹\$6.60 a hundred for the best varieties in 1910. At the same time mangos were selling in Florida for \$3.00 a dozen.

ley's "Cyclopedia of Horticulture" as follows: "In size and character of fruit the mango is extremely variable; there are varieties which are scarcely larger than a plum and there are others whose fruits weigh as much as four or five pounds. The shape varies from round to long and slender, some of the commonest types being reniform, obliquely heart-shaped, oval or elliptical. The skin is smooth, somewhat thicker than that of a peach, commonly yellow or greenish-yellow in color, but in some varieties bright yellow overspread with scarlet or crimson, and of extremely beautiful appearance. Other types are uniformly pale lemon-yellow. The aroma is often de-



A SIX-YEAR OLD DATE PLANTATION IN CALIFORNIA
Courtesy of the U. S. Bureau of Plant Industry.

licious, spicy and tempting, and this added to the brilliant color, makes some of the finer varieties of the mango among the most attractive of all fruits."¹⁰

The date palm, that wonderful tree of the oasis in the scorching deserts of Arabia and Africa, is now domesticated in Arizona and Southern California and has taken kindly to its new home. In the countries of the East the date is a staple food for the dwellers in the desert, and not a luxury as it is with us. With some trees bearing more than 100 pounds of dates an average profit of \$100 to \$150 per acre is a fair estimate.

¹⁰ Bailey, "Cyclopedia of Horticulture," p. 1986. By permission of the Macmillan Company.

And so we might continue *ad nauseam*, if not *ad infinitum*, to rehearse the achievements of Uncle Sam in levying tribute on the flowers and fruits, the grain and timber of all the world to beautify and enrich his country, but this brief sketch



A BUNCH OF DATES

Ripening in the desert region of southern California.

Courtesy of the U. S. Bureau of Plant Industry.

must suffice as a suggestion merely of the past accomplishments and future possibilities of the economic biologist in the discovery and cultivation of Nature's wealth of plants throughout the world.

The finds of the plant explorer must be carefully packed to ensure their safe arrival after a journey halfway around the world or more. Dry seeds such as grains or beans can be shipped in bags or boxes without any special precautions. Some nuts however which are liable to be parched or

frozen in transit, must be protected by moist material such as sphagnum moss, which seems to have an antiseptic function, and to protect the plants from infection and decay; and packed in strong boxes to protect the young sprouts in case of germination en route. Entire plants, or cuttings from them, are covered with the sphagnum and then carefully packed in bales or boxes for shipment.

Arrived in Washington each package is carefully inspected by an entomologist and plant pathologist to guard against the importation of insect pests or plant diseases, and if any immigrants are found concerning whose health the inspectors are in doubt, they are kept in quarantine in gardens near



BUFFALO ON NATIONAL BISON RANGE, MONTANA

One of the few remnants of the once mighty herds which formerly roamed the West.

Courtesy of the U. S. Bureau of Biological Survey.

Washington until all danger of infection is passed. Those which pass inspection are entered in the records of the office which include data giving the source of the plant, its uses, inspection, consignee, etc., and are then forwarded to the experimental gardens where they are to be propagated, or to the special experimenters in various parts of the country for whom they were obtained.

But not alone in foreign lands is the economic biologist seeking to increase the nation's wealth. Many are our natural resources unused as yet, while many another fast disappearing can be restored in part at least to its former abundance, not only by the negative measures of conservation, but by the active ones of propagation as well.

In the days of the pioneer the United States was teeming with game. Today the flocks of wild pigeons, the herds of buffalo, elk and antelope are but memories of the past, but a few wanderers remaining among the graves of their departed kin. Of the wild pigeon not one wild bird remains today to bear testimony to their departed glory. To save the others from a like fate the Biological Survey in co-operation with our National Park Service and the Audubon Society has established havens of refuge throughout the country, where the remaining herds of large game are safe from the



ELK IN WINTER IN YELLOWSTONE NATIONAL PARK

Photo by Haynes, St. Paul.

Courtesy of the U. S. National Park Service.

depredations of man, and others where our wild fowl may breed in safety and replenish their fast thinning ranks. The best known of these is the Yellowstone National Park, where the bears and elk, due to plentiful food and lack of molestation, have become almost as tame as domesticated animals. All of our national parks are "out of bounds" for the sportsmen, except for the ever increasing number of those who hunt only with the camera. In addition to the national parks there are five other big game reservations, all of them in charge of the Bureau, containing herds of elk, buffalo, antelope, and deer. All but the antelope are apparently thriving, thanks to adequate protection and winter feeding, when

the snow lies so deep on the ranges that the animals cannot forage for themselves; and the buffalo, which formerly appeared to be doomed, have probably been saved, although they are today more like domestic cattle, retaining little of the picturesque character of their forbears, which ranged in such magnificence over our western domain. But the antelope at present appears to be doomed. Even with the most careful protection the young often fall victims to the wily



AN EGRET COLONY IN SOUTH CAROLINA

The aigrette which formerly adorned women's bonnets so extensively was obtained from this bird, which was nearly exterminated as a result. Photograph of a group in the American Museum of Natural History in New York.

Courtesy of the Museum.

wolf and coyote, and the destruction which man began, Nature seems determined to finish.

Until comparatively recent times the swamps of our South Atlantic and Gulf Coast were the home of countless thousands of snowy herons, bearers of the beautiful "aigrette," which woman in innocent barbarity was at one time proud to wear. The story of the aigrette trade with all its wanton cruelty, has been told so often as to need no repetition here, but a word may be said regarding its suppression. Aboli-

tion of the feather traffic was one of the primary factors in the organization of the Audubon Society; and since the inception of the latter it has played a prominent part in the salvation of the few herons still preserved from their ruthless pursuers. Through its activity the Audubon model bird law has been passed by every state (among many others) where the egret colonies were found. But this law was inadequate because, like many another law, it proved in many places to be but a "scrap of paper." Especially was this true in the conservative and easy-going South, where public opinion was not yet alive to the necessity for bird protection, and so the Society turned its attention to the source of the trade, namely the millinery interests of our great cities, and after many a hard fight these interests were defeated, and laws were passed by many states prohibiting the sale of wild bird plumage. The Society, with the aid of other organizations interested in bird life, also secured a provision in the tariff act of 1913 prohibiting the importation of feathers into the United States, which for a time created much consternation among certain aigrette-bedecked ladies returning to this country from abroad.

The passage of this provision through Congress was only effected after a bitter fight against the forces of sordid greed. A fine example of the spirit of its opponents is afforded by the speech of a man who still figures in our legislature as a champion of reaction.

"I really honestly want to know why there should be any sympathy or sentiment about a long-legged, long-beaked, long-necked bird that lives in swamps, and eats tadpoles and fish and crawfish and things of that kind; why we should worry ourselves into a frenzy because some lady adorns her hat with one of its feathers, which appears to be the only use it has." . . . If the young are then left to starve, it would seem to me the proper idea would be to establish a foundling asylum for the young, but still let humanity utilize this bird for the only purpose that evidently the Lord made it for, namely, so that we could get aigrettes for bonnets of our beautiful ladies."¹¹

But not content with mere repression of the feather trade, the Society has devoted itself to the protection of the herons on their breeding grounds, establishing and patrolling many reserves along our coast, where they now live in peace and are multiplying rapidly.

In guarding these reserves two wardens of the Society have been shot by plume hunters angered at the interruption of their illegal trade.

¹¹ From remarks of Senator James A. Reed of Missouri. Cong. Rec., Vol. 50, p. 3426.

While the Audubon Society has been the foremost agency in egret protection, it has been aided by the U. S. Biological Survey, which now has in charge a number of government reservations, where not only egrets but other sea fowl breed in large numbers.

Private individuals also early came to the rescue of the birds and have aided in their protection both by contributions of money and by protection of the birds' nesting sites. One of the largest egret heronries existing today is the one on



SOME VALUABLE FUR BEARERS

A, Mink; B, Arctic fox; C, Silver fox; D, Red fox. From Jones, "Fur Farming in Canada."

Commission of Conservation, Canada.

Avery Island, Louisiana, established some twenty years ago by Mr. John Avery McIlhenny and Mr. Charles W. Ward with a few birds, and where there are now reported to be large numbers of these beautiful creatures.

The furry denizen of the north was the charm which lured the French adventurer into the depths of the Canadian forest, while an early map in which Newfoundland is described as "the land of the codfish" is evidence of the spell which the wealth of the waters cast about the early mariner. To-



OTTERS IN NATIONAL ZOÖLOGICAL PARK, WASHINGTON

The otter is one of our wild animals which is being cultivated for its fur.



MINK RAISED ON A FUR FARM

Fur farming is being developed extensively, especially in Prince Edward Island, and while still largely in the experimental stage gives promise of becoming a great and lucrative industry.

Courtesy of the U. S. Bureau of Biological Survey.

day the rôle of the beaver is being played by his humble cousin the muskrat, while fox and fisher, mink and martin are following in the footsteps of the buffalo, the elk and the antelope. The codfish still manages to hold his own, but many of his congeners are less fortunate.

The rapid diminution of our fur-bearing hosts, with the consequent rise in price of furs, has led to experiments in breeding these animals for market, which, while scarcely beyond the experimental stage as yet, give promise of future success. The principal site of these experiments has been Prince Edward Island, where the golden possibilities of fox farming have so seized upon the imagination of many of the local farmers, that they have mortgaged their farms to obtain the necessary capital for undertaking this venture. In 1911 the value of the captive foxes was twice that of all other live stock on the island. That enormous profits are possible in successful fox farming is shown by the value of the best animals for breeding, as high as \$25,000 having been paid for a single pair of silver foxes for this purpose. Not alone foxes, but fisher, martin, mink, skunk and other animals have been cultivated for their furs, and to aid this industry in the United States the Biological Survey maintains an experimental fur farm in Essex County, N. Y., where several species of fur bearers are being raised.

When those of us who are privileged to pay a surtax on our incomes and can accordingly indulge our appetites with such delicacies as blue points on the half-shell, lobster à la Newburg, or, shades of Epicurus defend us!, diamond-back terrapin stew, how often do we think of the part played by our benevolent Uncle Sam in providing us with such delights? Were the wealth of Nature used, but not abused by man, her resources would be never failing. But man is as stupid as he is greedy and gluttonous, and ofttimes destroys just for the sake of seeing the smash. Hence Artifice must come to the aid of Nature, and learning skill from her may soon come to outdo her in the production of her own wealth.

Nowhere has the propagation of wild animals been undertaken with greater effort or larger success than in the United States. Our waters, both inland and marine, form a vast aquatic farm wherein fish and other aquatic animals are being reared by the billion every year. Our biggest fish farmer is Uncle Sam himself, but a majority of the states are also engaged in the business on a more or less extensive scale.

The American Fish Cultural Association was organized in 1870, later becoming the American Fisheries Society, and several states had already established fish commissions. Through the activity of these agencies the Federal Govern-

ment was induced to establish the U. S. Fish Commission in 1871, under the leadership of the late Professor Baird, whose name occupies so prominent a place among the makers of American biology. In 1903 the Commission became the Bureau of Fisheries in the newly organized Department of Commerce and Labor.

To describe in detail the work of the Bureau since its inception would in itself require a small library. All that can be done here is to touch briefly on a few of its activities illustrating the achievements of biology in the conservation and creation of wealth. Fish propagation was not one of the functions included in the original program of the Commission, but was undertaken by it shortly after its inception, and has since become its most important service. The first fishes propagated were the shad, Atlantic salmon and the whitefish of the Great Lakes. The success of these early efforts has caused the extension of the practise to most of our important food and game fishes. In 1921 the number of eggs, young and adults of some fifty species of fish and the lobster distributed by the Bureau totalled 4,962,489,405. At least that is the figure given in its annual report. To attempt to estimate to units so inconceivably large a number is in the nature of the case an absurdity. Five billion in round numbers would probably be as nearly accurate as the figure given. We cannot here describe the various methods employed in propagating these many species. To illustrate the methods of the Bureau however, we may describe its work in the propagation of the Pacific salmon.

There are five species of salmon found on our Pacific Coast, which were described as early as 1768 by the naturalist-explorer Steller, and a Russian investigator with the appalling name of Krascheninikov. Since the life history of each differs only in minor details, we may tell the story of all in giving that of the principal one, which passes under several aliases, namely, "king," "quinnat," "chinook," "spring," "tyee," "Columbia River," "Sacramento," "tchaviche" and last and worst of all—*Onchorhynchus tshawytscha*. The "king" salmon occurs on both coasts of the Pacific from California and China north to Behring Straits. The average weight is twenty-two pounds, but one giant was taken in Alaska in 1909 weighing 101 pounds minus the head. During the winter the fish sojourn in the sea, but in early spring they slowly gather in the rivers, especially the large streams like the Sacramento, Columbia and Yukon, and begin the long and arduous journey to their breeding grounds, which in the Yukon may be over 2,000 miles from the sea. In the ascent of the rivers they perform prodigious feats,

ascending falls 10-15 feet in height. Arrived on the spawning grounds in autumn the male excavates a little hollow in the gravel of the stream bed, where the female deposits her eggs, upon which the male sheds the "milt," after which they cover them with gravel; and then the function of reproduction performed, which is the crowning act in the life of either animal or plant, they float downstream to die.

Perhaps nowhere else among animals is there shown a more striking example of the influence of the sex organs upon body form and general metabolism than in the male salmon. In the spring he is a perfectly respectable looking fish, but as summer advances and his sex glands ripen, the jaws become greatly distorted, so much so in fact that in some cases, it becomes impossible for the fish to close them. Some of the teeth may disappear, while others grow very long. The body becomes compressed and assumes a distinct hump in the back.

The average number of eggs laid by a female salmon is four thousand. If one-half of these developed into females and reached maturity in four years, and if their progeny in turn were all to reach maturity, one-half being females, this rate of increase remaining constant from generation to generation, there would result in 32 years 256,000,000,000,000,000,000,000,000 salmon weighing 2,816,000,000,000,000,000,000,000 tons or 468 times the mass of the earth.

Why is it that such increase is impossible? Let us see what are some of the dangers which the salmon encounters in its journey to its spawning grounds far distant from its ocean home, and what those which await the eggs and fry. Near the mouth of the salmon stream lurk the trollers seeking to entice them with shining lure. Here too, and in the broad reaches of the lower river, are the seiners, sweeping the waters with their nets. Where the river begins to narrow so that a definite channel is established, the fish encounter traps and weirs to stop them in their course; while higher up, where the river narrows still more, the fish wheel bars their progress. This is an ingenious device constructed somewhat on the principle of a Ferris wheel. It is placed where the river is narrow and the current swift, and the river is usually still further narrowed by means of a net or barricade of some sort to oblige all ascending fish to pass through the channel where the wheel is placed. Upon its rim are wire baskets which catch the fish as they try to pass through the narrow channel, and as the wheel turns empty the fish into a spillway or sluice which carries them to a pool where the fisherman is waiting to receive them. Some of these fish wheels are movable, being attached to the tail of a scow, if

a scow can properly be said to possess such an appendage, and can be taken from point to point, at the will of the fisherman. And if any luckless fish chance to pass all of these devices for his destruction, he must yet run the gauntlet of the Indian waiting with his spear upon some platform in the river, or following his finny prey in swift canoe.

But the wiles of man are not the only danger which the salmon must overcome in his struggle for existence. There is the danger of the fungus which takes such a heavy toll of the eggs, and there is many a lurking enemy of the finny



SEINING SPAWNING SALMON FOR AN ALASKAN HATCHERY

Courtesy of the U. S. Bureau of Fisheries.

tribe to whom a meal of young salmon or of salmon spawn does not come amiss. Many an enemy too is there in feathers and in fur, waiting by the salmon streams for their share of the fishing, among which are the gulls and bears, while the seal is not averse to a meal of salmon; and many a smaller member of the furry tribe skulks by the streams to prey upon the harried fish.

From the data of the canning industry between 1866 and 1915, published in a recent report of the Bureau of Fisheries, there appears to have been no material decrease in the number of cans of salmon packed on the Pacific Coast during that period. Indeed there has been on the contrary a consistent

increase, due probably to increased facilities for taking and preserving the catch.

The survival of the salmon in the face of so great difficulties is undoubtedly due in large measure to the extensive propagation carried on mainly by the government, but also by state and private concerns.

From California to Alaska the Bureau of Fisheries maintains salmon hatcheries, which annually distribute in our waters some 200,000,000 eggs, fry and older fish. Since the start of propagation work in 1872 to the end of 1921 a total of about 4,000,000,000 salmon eggs have been hatched and "planted" in Pacific waters, besides those which have been sent to the Atlantic Coast and to foreign countries. The hatcheries are located on some salmon stream, where there



TRAY OF SALMON EGGS

Courtesy of the U. S. Bureau of Fisheries.

is an abundant supply of good water and plenty of fish from which to strip the eggs. The fish are caught on their way to the spawning grounds, either by seining them from the river, or in a trap, and if not "ripe" (i. e. ready to shed their sperm and eggs) they are retained in a pound or enclosure until the proper time. In obtaining the eggs two methods are employed, either the living fish is "stripped" of her eggs, or she is killed, opened and the eggs removed. The latter method causes no loss of fish as might appear at first sight, since the fish die after spawning in any case; and is more efficient than the former, since all of the eggs are obtained, which is not the case in "stripping." In "stripping" the female, she is held in the hand or placed in a special frame for this purpose, while the "stripper" runs his thumb down her belly and squeezes out the eggs into a pail. The sperm or "milt" of the male is obtained in the same way. After

the eggs and sperm have been taken they are mixed together either in their natural condition or in a little water. The eggs are then allowed to harden for an hour or so before they are transferred to the hatching troughs. In this mixing of eggs and sperm fertilization occurs, while the hardening process renders them tougher and less liable to injury than if they were transferred to the troughs directly after fertilization. These latter are long shallow troughs divided into compartments about two feet long, a foot wide and six inches deep. In each compartment is a wire basket in which



INTERIOR OF A SALMON HATCHERY
Courtesy of the U. S. Bureau of Fisheries.

are placed about 30,000 eggs. Any eggs which become fungussed or otherwise diseased are removed daily to prevent communicating the infection to other eggs.

At first the young fish is a sack filled with yolk. Soon the body appears as a narrow band extending a third or half way around the sack. This little band represents mainly the brain and spinal cord, back-bone and muscles of the future fish. Soon the brain begins to enlarge and the eyes appear as two black spots on either side, and the little fish is now all head and eyes. Meantime the body is being lifted up and constricted off from the yolk sack, which becomes covered with a network of delicate blood vessels, connected with the heart which bulges out beneath the head, for the young fish

may be truly said to have "its heart in its throat." The tail meanwhile is forming and head and tail bend toward each other until they almost touch, while the yolk sack appears like a great tumor upon the belly of the young fish, which soon begins to try its muscles in spasmodic jerks and twists. Prior to hatching the little embryo is surrounded by the delicate and highly extensible membrane which surrounded the egg. At time of hatching this membrane is broken, the food stored in the yolk sack is soon absorbed, and the young fish begins to "rustle for a living." At this stage the fry may be set free in the river, or if suitable ponds are available, they may best be kept at home and fed on chopped liver, meat, milk curds, etc., for several months until they are better able to take care of themselves. For the whole



DEVELOPING FISH

Showing yolk sack. From Kunz & Radcliffe, Bulletin of the U. S. Bureau of Fisheries, Vol. 35.

principle of fish culture is that a greater per cent of eggs will be fertilized artificially than in nature, and a larger number of them will develop safely in the care of the hatchery than if exposed to their hosts of natural enemies.

While the seal and whale are not fishes, the Bureau of Fisheries, on the basis of the old scriptural classification of "beasts that swim," has included them and all other creatures aquatic in the field of its activity. The fur seal industry is but one among many examples of the influence of natural wealth upon human history. The fur seals of the Pacific are grouped in two main herds, those of the Pribilof, and those of the Commander Islands. The former are part of Alaska and the latter of Siberia. The former herd was discovered in 1786 by the Russian navigator Pribilof, whose name is borne by the islands of his discovery, and the latter in 1741 by the naturalist Steller who accompanied the ill-fated Behring on his second and final voyage in 1741. A few years ago the seals were threatened with extinction, the Pribilof herd having suffered reduction from its original number of four or five

million animals to about four hundred thousand. The early abortive efforts at protection of the seals are but one of many striking illustrations of the folly of so-called "practical" economists and amateur legislators to control natural wealth without any adequate knowledge of the methods of its production.

The fur seal leads a roving and picturesque existence. As a pup he gains acquaintance with Nature in a wild and savage mood. His puppyhood is spent amid the rocks and breakers of the bleak and barren islands of the north Pacific. When a few months old he makes a long sea journey with his mother to the south and spends his first winter fishing off the California Coast. Early each summer he returns as a young "bachelor" to the ancestral home, where he lives with fellow "bachelors," while the old seals are rearing a new lot of puppies. When five or six years old the mating instinct grows strong within him and on his arrival at the breeding grounds he selects for himself a little patch of rocks in which he establishes a "harem," which may number from thirty to one hundred females, depending on his success in "rounding up" the "cows." During this time, like a jealous lover, he stands guard over his "harem," engaging oftentimes in combats to the death with intruding "bulls," not leaving his stand for about two months, even to feed, and becoming greatly emaciated during the summer as a result of his long fast. Soon after the arrival of the females the young (usually but one) are born, shortly after which mating occurs, gestation lasting a year. During the nursing season the mother seals frequently leave their puppies and make long journeys to sea in search of food, and it is at this time that the destructive effects of pelagic sealing are most apparent.

Sealing privileges in Behring Sea have long been a bone of bitter contention between Americans, Russians, Canadians and more recently the Japanese. The Pribilof Islands, the principal sealing grounds, originally belonged to Russia, the sealing rights on the islands, being a perquisite of the government. With the sale of Alaska to the United States in 1867, these rights passed to our government, and for forty years were leased by it, as had been previously done by Russia, to private concerns. For this lease the government received \$50,000 annually besides a royalty of \$2 a head, and it is an interesting commentary on the foresight of the opponents of the Alaska purchase proposition, that from 1870 to 1890 our government received in leases, royalties and duties on furs made up in London, but most of which came originally from Alaska, some \$13,000,000, or nearly double the price paid for the entire territory.

Sealing on the islands is restricted to the "bachelor" herd, the number taken each year being determined by the government. The seals are rounded up and driven by a number of native drivers to the killing pens where they are slaughtered by a blow on the head with a club. The skins are then removed and packed in salt for shipment to market.

Despite the restrictions on the killing of the seals, the herd rapidly diminished to about one-tenth of its original size. It was simply a repetition of "watching the spigot" while the "bung-hole" was allowed to take care of itself. The



A SEAL ROOKERY ON THE PRIBILOF ISLANDS, ALASKA

Courtesy of the U. S. Bureau of Fisheries.

seals may be ever so well protected on their breeding grounds; but if allowed to take care of themselves elsewhere they are doomed to destruction.

Realizing the threatened extinction of the herd by pelagic sealing our government decided to avail itself of a right claimed by Russia in 1821, but never tested, of seizing all vessels engaged in pelagic sealing in Alaskan waters, whether within the three-mile limit or not. This immediately brought on a controversy with Great Britain, whose Canadian subjects were the ones chiefly affected. The result of this controversy was arbitration before the well-known Behring Sea Tribunal, which sitting in Paris in 1895 decided adversely to the United

States, and then proceeded to formulate regulations, governing both parties to the controversy, and designed to furnish adequate future protection to the seals. But, like most third parties to any controversy, the seals were inevitably the sufferers. The regulations prohibited pelagic sealing within sixty miles of the breeding grounds, but since the female seals wander far outside this limit, their destruction continued as before. Now the death of one female during the summer means the destruction of three seals—the mother, her unborn young (for most females are gravid at this time) and the young of the year, left to starve in its rocky home on the breeding grounds. The matter was finally adjusted by Russia and the United States, the owners of the rookeries, granting to the Canadians and the Japanese, who had entered the field in 1903, fifteen per cent each of the profit from land sealing, in consideration of their abandoning pelagic sealing altogether. As an additional protection the United States declared a closed season on the Pribilofs from 1912 to 1917, at which time the herd had shown some increase, numbering over 450,000 individuals. Sealing was resumed in the latter year and is being prosecuted at present under the direction of the Bureau of Fisheries.

In respect to the whaling industry, which formerly played so large a part in our maritime industries, the Bureau has done little more than publish annual statistics and some data relative to the utilization of whale products. In the nature of the case propagation of these animals is impossible and the most that could be done is the imposition of a closed season, which would be exceedingly difficult owing to the cosmopolitan character of the whale. Only through international agreement could this be effected, and hitherto, so far as the writer is aware, no steps have been taken in this direction.

The use of whales thus far has been limited mainly to the skin, oil, "whalebone," ambergris, bone meal, tallow, glue, etc. The use of the meat has been restricted largely to "pemmican" for the Esquimaux and arctic explorer, although the Japanese have used it as food for some time, and it is now finding a place on the tables of Europeans and Americans.

One of the recent activities of the Bureau has been, as one wag expresses it, to "knock H. out of the High Cost of Living." In so doing it is finding new food supplies among our aquatic animals and educating a highly prejudiced and fastidious public regarding their use. "What's in a name!" If offered "dogfish" we are highly incensed at the indignity, but "canned grayfish" sounds, and therefore tastes, much better. Just as Milady takes greater pride in a beautiful set

of "black marten" than in the same set of skunk fur. In a recent pamphlet issued by the Bureau we find thirty-two recipes for the preparation of whale meat, some by so high an authority as Delmonico himself. In another we are given seventeen methods of preparing "grayfish" alias "dogfish" or shark, while still others tell us of the gastronomic possibilities of "goosefish," "bow-fin," and other hitherto neglected possibilities of human aliment.

"Acres of diamonds" are indeed on every hand. It is not many years since dwellers along the Mississippi and its tributaries were accustomed to cast aside as "worthless" the mussel shells which they found on the banks of the streams. But in 1894 two button makers from near Hamburg visited



A GLOCHIDIUM

The larva of a fresh water mussel. By means of the valves of its shell it attaches itself to the gills or fins of a fish and grows there as a parasite until it reaches the adult form. After Lefevre and Curtis in "Journal of Experimental Zoölogy," Vol. 9.

the Mississippi and today more than \$3,000,000 are invested in establishments for the manufacture of buttons from mussel shells, with an annual output of over \$5,000,000 and employing about 8,000 people in 1918. But in this case, as in so many others, the greed of man soon bade fair to ruin a promising industry. So closely were the river bottoms raked for shells, that in a few years there were not enough mussels left to keep up the supply, and the end, or at least serious curtailment of the industry appeared probable in the near future. But now enters Uncle Sam upon the scene, calling upon biology to aid him in finding a remedy. To prescribe a remedy the physician must first be able to diagnose his case. And so the first thing which the biologists did was to study the life history of the mussels in order to learn how Nature herself maintained the supply.

After fertilization the eggs are lodged in special chambers

in the gills of the mussel which hang in sheets between either valve of the shell, and the internal organs. Here they grow until they attain what is known as the glochidium stage, when the young mussel possesses a shell of its own, with paired valves. They are now set free in the water, and should they be so fortunate as to come in contact with certain species of fish, chiefly those of the sunfish family, they attach themselves to the gills or fins by means of their valves and force the fish to become their foster parents. The food of the young mussel at this stage is obtained from the tissues of the fish which acts as foster parent, in which they become embedded, living as parasites upon the latter. After ten to forty¹² days of this indolent existence, during which time the glochidium is metamorphosed into a mussel, it drops to the bottom of the river or pond and burrowing into the mud or sand, proceeds thereafter to find a living for itself. This it does by means of a tube or siphon, which it thrusts up to the surface of the river bed, from the bottom of its burrow, and through which there circulates a stream of water carrying in oxygen, and food in the form of minute plants and animals or finely divided bits of organic matter of any sort, and carrying out carbon dioxide and other wastes.

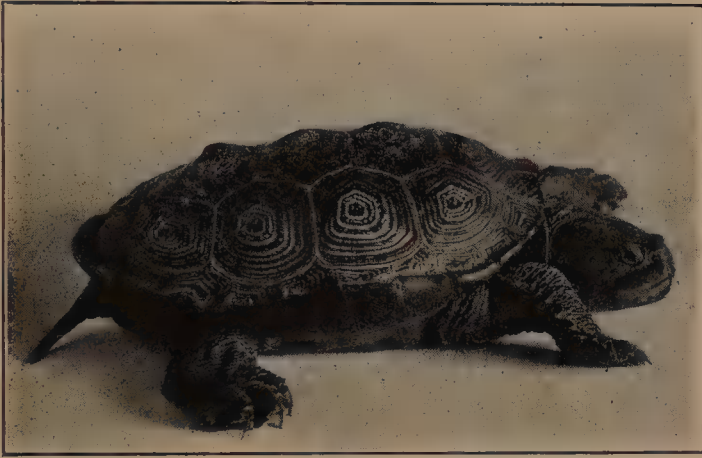
The task for the mussel culturist then is to secure the glochidia from the gravid mussels and find foster parents for them. This is done by placing the young glochidia obtained from the mussels in tanks containing the proper number of fish of the right species to carry successfully the number of glochidia provided. The extent of infection by glochidia which any given fish can stand is a matter of importance, for if loaded too lightly, there is a waste of time and effort in securing more fish than necessary, while if loaded too heavily the fish may not survive the strain put upon it, and both fish and glochidia are lost. The optimum number of glochidia varies for different species of fish. A young bass or sunfish, three to four inches long, will carry successfully as many as 1,000, a number which will kill many other species.

Our knowledge of the life history of the mussels is largely the result of the investigations of Curtis and Lefevre at the University of Missouri. Their studies have been continued and amplified at the Bureau of Fisheries station at Fairport, Iowa, where the practical propagation of mussels has been conducted for several years. In 1918 fish carrying more than 200,000,000 glochidia were set free, but no definite facts of mussel increase as a result of the work are yet available.

¹² In one case a period of six months has been recorded.

While the primary function of this station is mussel propagation, it interests itself also in saving the multitude of fish found in the overflow waters of the Mississippi bottoms, and to which reference has already been made.

Living a humble life in the salt marshes of our Atlantic and Gulf Coast is the delight of the epicure—the diamond-back terrapin. So precious is this creature in the eyes of some persons of elegant and expensive tastes that the best grade of Chesapeake terrapins were bringing about \$70 per dozen in 1917. Here surely was an opportunity for the economic biologist. The Bureau promptly rose to the



THE DIAMOND-BACK TERRAPIN, AN EXPENSIVE TIDBIT

Photo by R. W. Shufeldt.

emergency and in 1902 established a station at Beaufort, N. C., for the study of various economic and scientific problems relative to the fisheries of the region, and more especially those concerning the propagation of the terrapin. In the pens connected with the station are more than two thousand terrapin including some ten generations, which have been raised in captivity. Many of these are now large enough for market, and some have in their turn produced young. The experiments, the details of which cannot be given here, demonstrate the possibility of terrapin farming on a commercial scale, and establishing in this manner a lucrative industry. A terrapin farm on a commercial basis has been conducted for many years near Savannah, Georgia, by Mr. A. M. Barbee, where terrapin are raised for market by the thousand, so that terrapin farming may now be fairly said to have passed the experimental stage.

But not alone in commerce has biology played its part. It has entered the courts of justice and aided in disentangling the knotty problems of the law.

In murder trials the guilt or innocence of the accused may hinge upon the kind of blood in a stain upon his clothes, whether human or not. Until recently there was no certain test. But through the discovery of the blood test, made chiefly by the English physiologist Nuttall, we now know how to determine this. For if human blood be injected into a rabbit, there develops in the blood of the latter an "anti-body" which produces a white precipitate with human blood. All that is necessary then, in diagnosing a blood stain, is to soak the piece of clothing in salt solution and mix a little of the latter with the "anti-human serum" from the rabbit, a resultant white precipitate indicating the presence of human blood. An interesting corollary of this discovery is the fact that "anti-human serum" will produce a precipitate, though not so marked, with an ape's blood, and that the amount of precipitate formed decreases progressively the less close the relationship between man and the animal tested.

Not many years since the U. S. Department of Justice found itself in a muddle over the status of certain lands in the Mississippi "bottoms" in eastern Arkansas. These lands were covered by timber of great value and were furthermore very valuable for agriculture after the timber was removed. Now it so happened that certain lumber "barons" having exhausted the supply on neighboring lands began casting covetous eyes upon the rich "bottoms." In 1847 when the original survey of this district was made the land in question was entered on the maps as "permanent lake." So the barons decided to gain possession, not by purchase of the lands, but by purchase of "riparian rights" along the old "lake" shore, which according to the law would entitle them to possession of the "lake" bottom, when the latter receded or dried up. But Uncle Sam threw a clog into their nicely oiled machine by bringing suit against them on the grounds that the survey was wrong and that lakes had existed there in the imagination of the surveyors rather than upon the lands themselves. Then the Department of Justice turned to the biologist for assistance and asked Professor Cowles of the University of Chicago to appear as an expert witness.

There were many lines of evidence which Professor Cowles found, all closely related and corroborative one of the other. These were in part botanical and in part physiographic. He found for example that at the time when these supposed lakes existed there was an upland forest standing there of great age. The lumber interests tried to show that many trees

such as the cypress and tupelo gum may grow in standing water, but Professor Cowles countered by showing that even these hydrophytic or water-loving types are killed by too deep or too long submergence, and that further the timber occupying the disputed ground was composed of oaks, hickories, cottonwoods and other upland types, rather than by the swamp dwellers of the forest. Physiographic evidence likewise supported the story of the trees. The disappearance of a lake is due to one of three causes, evaporation, draining and filling. The rainfall of the lower Mississippi Valley is too great to admit of the first explanation, and the character of the land is such as to preclude the second, leaving the last as the only one of the three explanations possible. But in these bottoms there lie the unburied trunks of trees overthrown in a great earthquake of a century ago. Had they fallen in lakes, which were subsequently filled in by *débris*, they must surely have been covered during the disappearance of these lakes.

Other evidence there was, the details of which need not be elaborated here, but to make a long story short the judge of the district court at Little Rock, gave a verdict against the lumber companies in spite of the fact that some of the "oldest inhabitants" testified at the trial to having actually seen the lakes in question. In the words of Professor Cowles—"It is safer to believe a tree than a man."

Why were the "lakes" originally recorded on the survey? The old surveyors received so much per mile for their surveys, and "per" meant more for their purse when lake shores were surveyed because of the greater difficulties involved in such surveying. Hence many of the old maps are probably more or less "scraps of paper" and not representations of fact.

In the preceding pages we have hastily sketched a few of the achievements and opportunities of economic biology in America. Much has of necessity been passed by, but enough has been given to illustrate the indispensable place which biology has in our economic structure.

CHAPTER XVI

Biology and medicine. Microscopic life and its relation to human health. The rôle of animals in spreading disease. Animal experimentation and its contributions to human welfare. The new medicine, safeguarding the health of the nation.

Nowhere has the service of biology to man been so conspicuous as in the field of preventive medicine and public sanitation. While the entire field of medicine is strictly speaking a biological one, yet the study of the human mechanism in health and disease holds a special place in science, peculiar to itself, and it is only in so far as our knowledge of plants and lower animals contributes to human health that we shall consider medicine, or more properly speaking, sanitation, a province of biology.

In days gone by the doctor's chief duty was to heal the sick; today his main function is to keep men well. The greatest medical progress of all time has been in the prevention of disease. It is the knowledge of microscopic life that has rendered this progress possible, a knowledge for which the world is indebted to biology.

In bacteriology no American ranks with Pasteur, Koch or Jenner. Yet America has not lacked men noted in bacteriological science, and in its practical application she ranks second to none. Nowhere in all the fields of human endeavor has a greater contribution to human welfare been made than in the discovery of the world of unseen things about, and within us, the bacteria and the Protozoa, and the recognition of the part they play in causing human disease. This discovery has revolutionized medical practice, created the new science of sanitation, reclaimed vast areas formerly uninhabitable by the white race, virtually wiped out of existence some of the worst scourges of mankind and saved countless human beings from death and misery. This debt we owe to biology. The story of this revolution would in itself fill volumes, and is in its general outline so widely known that its repetition here would be prosaic. And yet of common knowledge how little there is that each of us can call his

own! We are so accustomed to things as they are, that only the historian thinks of things as they have been, while the constructive prophet is as rare among us as the proverbial hen's teeth. How often do we go back in memory to the days of the market basket, when the telephone was not at hand to bring our dinners to our doors, or the coal oil lamp, and the gas lamp post; while the days of the horse car and horse carriage, will soon be classified as the "age of horses," not clearly distinguishable in our minds from the "age of reptiles," "Amphibia" or "fishes." It may not then be amiss to contrast for a moment some pictures of the past and present in medicine and public health.

At the time of the great smallpox epidemic in 1752 Boston had a population of 15,684, of whom 5,998 had had the disease, leaving 9,686 persons who were susceptible to it. Of these 7,669 contracted the disease, 5,545 by contact and 2,124 by inoculation (in order to produce a mild type of the disease and escape its danger) and 1,843 persons left the city, leaving but 174 who, without the immunity furnished by a previous attack, faced the disease, but were not stricken. The history of smallpox in the cities of Europe in pre-vaccination days is one long record of despair and death. In America the disease introduced by the early explorers swept like wild-fire among the natives who proved peculiarly susceptible to it, carrying away, according to early historians, whole tribes, and reducing others to mere remnants of their former selves. One of these writers (Catlin) gives it as his opinion that at least one-half of the Indians of North America were taken by smallpox. Quoting from Parker he says of the Indians below the Falls of the Columbia that at least seven-eighths, if not nine-tenths, were destroyed by smallpox between 1829 and 1836. Prior to the advent of the United States in the Philippines there were more than 6,000 deaths in seven provinces annually from smallpox.

Turning now to the other side of the picture we find a conspicuous decrease in smallpox after the introduction of vaccination, while in countries where vaccination is compulsory, the disease scarcely exists. In 1905 and 1906, 3,094,635 vaccinations were performed by the U. S. Bureau of Health in the Philippine Islands. In the report of the director (Doctor Victor G. Heiser) of 1907, he says: "In the provinces of Cavite, Batangas, Cebu, Bataan, La Union, Rizal and La Laguna, where heretofore there have been more than 6,000 deaths annually from smallpox, it is satisfactory to report, since the completion of vaccination in the afore-

mentioned provinces more than a year ago, not a single death from smallpox has been reported."¹

From 1901 to 1904 smallpox was epidemic in Philadelphia. During that time the Municipal Hospital received 3,500 cases, about 80% of all cases in a city with a population of 1,293,000 and of these not one had been recently successfully vaccinated. Compare this record with that of Boston in the epidemic of 1752. In this same hospital "during a period of thirty-four years, in which time almost 10,000 cases of smallpox were treated, there was no instance of a physician, nurse or attendant, who had been successfully vaccinated or revaccinated prior to going on duty contracting the disease."²

The earlier method of protection against smallpox by inoculation from a person who already had the disease met with strenuous opposition in many quarters. During an outbreak of smallpox in Boston in 1821-3 this practise, which was advocated by Cotton Mather and others, aroused such intense feeling that an attempt was made to assassinate the worthy divine by the time-honored method of throwing a bomb into his house, which fortunately however failed to explode. It was accompanied by a message couched in these affectionate terms: "Cotton Mather, you dog, Damn you: I'll inoculate you with this, with a Pox to you."

When Jenner introduced his method of vaccination with cowpox, it was supposed by the ignorant that children when vaccinated "developed horns, hoofs and tails and bellowed like cattle."

Such primitive prejudices may be pardoned, but what shall we say of those who, in supposedly educated and civilized communities, oppose a remedy which has done so much in the relief of human misery and the prevention of death.

In a recent examination given by the writer to a class in elementary hygiene, one of the questions was "State the most important information gained by you in this course." In reply to which he was surprised to receive from several students answers which summarized ran about as follows: "The most important information I gained in the course was that regarding vaccination and similar remedies. I had always been rather afraid of, or at least skeptical about it, but now that I have learned its results, and the care taken in its use, I believe in it, and have no further fear of it."

A mysterious remedy such as vaccination might be expected to frighten or repel the primitive and the uneducated. An

¹Schamberg, "Vaccination and Its Relation to Animal Experimentation," *Defense of Research Pamphlet*, 1, p. 34.

²*Locus citatus*, pp. 35-9.

amusing instance of this is cited by Bennett in his "History of the Panama Canal": "When it was announced that they had to be vaccinated, one of their number, a voodoo doctor, led a mutiny against inoculation, in which a hundred and fifty took part. He pronounced it an attempt to put 'the inextinguishable mark' upon them, so that they could never escape from the isthmus. They declared they would rather suffer martyrdom abroad than to be held captive ashore, and it was only after three days of unsuccessful parleying that the mutiny was broken up by their being driven ashore by the police. Still protesting they were rounded up, in spite of their efforts to escape, vaccinated, and the next day sent to work."³

And yet more astonishing is the fact that much of the organized opposition to vaccination should emanate from a city which prides itself upon being the intellectual center of America. Surely extremes have met, when so-called "Science" and Voodooism walk hand in hand.

Prior to the days of Lister, the great surgeon of Glasgow and Edinburgh, the discoverer of antisepsis and the creator of modern surgery, the work of the surgeon was a continual nightmare.

The condition of a patient after operation was often too horrible for description. Erysipelas, lockjaw, blood poison and gangrene were frequent consequences, but since the coming of antiseptic surgery such conditions have been unknown. There is nothing wonderful or difficult about the modern antiseptic treatment of wounds and operations, nothing but the painstaking observation of scrupulous cleanliness and the careful sterilization of the wound or skin itself and of everything coming in contact with it, but today, blood-poisoning, tetanus or gangrene following an operation are virtually unknown.

In the pre-antiseptic period the surgeon dared not operate upon the brain, or upon the internal organs except as a desperate "last hope," for death was almost sure to follow. Today abdominal operations are an everyday occurrence and brain surgery is a common practise. In the olden days ovarian tumors in women were left until death appeared inevitable if the knife were not used, and the most famous surgeon in America lost two out of every three of such cases, while today tumors, weighing in some cases twice as much as the patients themselves, are removed, and the death rate instead of being over sixty is about one per cent.

Prior to the days of antiseptic surgery the Cæsarean opera-

³ Bennett, "History of the Panama Canal," p. 124. Historical Publishing Company.

tion, or opening of the abdomen of the mother to remove the child, was so fatal that even as late as 1887 Harris, an American physician, stated that the operation could be performed more successfully by a mad bull than by the best surgeon in the best hospital in America, supporting his statement, with evidence from nine cases in which the abdomen of pregnant women had been gored by bulls, in five of which the victim recovered, whereas in the eleven Cæsarean operations previously performed in New York there were but two recoveries. Today, on the contrary, Cæsarean operations are relatively common, and the mortality has been reduced to about two per cent.

In the days before the practice of antiseptic methods, every woman who entered a maternity hospital truly went down into "the valley of the shadow of death." Conditions in the lying-in hospitals of Europe were horrible in the extreme, while in America we were but little better off. For thirty years prior to 1833 in the Pennsylvania Hospital in Philadelphia fifty-six mothers in every thousand were victims of puerperal or child-bed fever, while in the Bellevue Hospital in New York in 1872 nine out of every fifty mothers succumbed to the disease, and similar conditions prevailed elsewhere. It was this awful fatality which called forth Dr. Oliver Wendell Holmes' famous paper on the "Contagiousness of Puerperal Fever." With the coming of antiseptic methods the mortality from this scourge of women has been reduced in good hospitals to less than one-fourth of one per cent, whereas formerly it ranged from two to twenty per cent, or even more.

But it was not alone the mother who suffered from this dread scourge. The child likewise was its victim, with almost invariably fatal results. Tetanus or lockjaw also levied its toll upon the new-born babes. Today in properly conducted hospitals puerperal fever in infants is almost never seen, while Professor Williams of Johns Hopkins says that he has never seen a case of tetanus in more than 10,000 new-born infants under his care.

One of the most wide-spread, insidious, and appalling diseases common to man is syphilis, the so-called "red plague." Exact data regarding its prevalence in the United States are lacking, but the best available estimates place the figures at from 2% to 20%. If we accept 5% as a fair average, this means that over 250,000 in New York City are victims of the disease.

Two and twenty-three hundredths per cent of the recruits drafted into our national army in 1917 were found on examination to be infected with gonorrhea, while of 1,300,000

(in round numbers) men inducted into all branches of the army that year 71,955 men or five and a half per cent were found to have venereal disease of some sort, most of which was brought with them on their entrance into camp. After enlistment the rate materially decreased, due to the vigorous methods adopted by the army, both for repressing vice about the army camps, and for educating the men and otherwise guarding them against this evil. Perhaps the worst feature of syphilis from the standpoint of its prevention is the difficulty of recognizing it in its latent form. Its transmissibility from husband to wife and *vice versa* and from parent to child is well known. But the disease is curable and marriage of a former syphilitic is permissible when such cure is definitely established. The difficulty is to determine when such cure has been established. An individual with no apparent symptoms of the disease may yet be infected and capable of infecting consort and children. Here too has lain the chief medical difficulty in the control of prostitution. Another very serious feature of the disease is the difficulty of recognizing it in its incipient stages. The earliest symptom of the disease is the chancre or sore, which appears usually about three weeks after exposure, and then often cannot be diagnosed with certainty. If treated immediately upon its appearance it disappears, a positive diagnosis cannot be made, and treatment will probably be relaxed or abandoned altogether, leaving the disease latent in the body, to break out anew at some future time. On the other hand, if treatment is delayed until a positive diagnosis is established valuable time is lost, and the disease may obtain so firm a hold upon the system that its eradication becomes extremely difficult if not impossible. Biology has largely solved these difficulties by providing means of diagnosis, even in the absence of all external symptoms.

If a small amount of sheep's blood be injected into the body of a rabbit there develops in the blood of the latter the power to break down the red corpuscles of the sheep, liberating the coloring matter or hæmoglobin which they contain. In this rabbit's blood are two chemical substances, one of which destroys the sheep's corpuscles in the presence of the second substance, the three forming a chain (according to modern bacteriological theory) a-b-c, a being the sheep's corpuscles, b, the go-between substance or "amboceptor," and c, the destructive substance, or "complement." The latter is probably present normally in the blood of any higher animal, it is the former or "amboceptor" which is formed by the injection of the sheep's blood into the rabbit. This rabbit's blood is now heated to 133° F. in order to destroy its "com-

plement." If the liver of an unborn or newly born child infected with syphilis (such bodies may frequently be obtained from autopsies) be extracted with alcohol a substance "antigen" is obtained which has been secreted by the germ of the disease, the *Treponema pallidum*. This substance we may designate as a' .^{3a} It likewise forms a chain with complement c in the presence of amboceptor b , which we may represent as $a'-b-c$. In the language of the bacteriologist it "fixes" or "anchors" the complement. The blood serum of the person suspected of an infection with syphilis is also heated to 133° F. to destroy its "complement." The "antigen" is now mixed with the blood serum of the suspect and a definite amount of guinea pig serum containing free "complement," which has not been heated, is added and the whole placed in an incubator or oven for an hour and a half. If the suspect is syphilitic, his blood will contain the amboceptor b , which has been developed there through the presence of the germs of the disease. In this case the antigen a' will combine with the complement c of the guinea pig, through the medium of the amboceptor b , present in the suspect's blood. If, on the contrary, the suspect is free from infection no amboceptor will be present and the antigen will not be able to fix the complement in the guinea pig's serum. A definite amount of the rabbit's blood mixed with the sheep's blood is now added and in the former case (presence of syphilis) no reaction will occur, the complement being fixed. In the latter case however (syphilis absent) the complement will be free to combine with the amboceptor in the rabbit's blood, the first reaction ($a-b-c$) will occur and the red corpuscles of the sheep will be broken down with liberation of their hemoglobin.

This test, known from its discoverer as the Wassermann test, is not absolutely certain, but it is efficient in probably 90% of the tests made. If it is repeated at intervals for two years after the disappearance of all active symptoms, and a negative result obtained each time, the patient may with reasonable certainty be considered cured.

There has recently died in Germany a man whose name is destined to be ever bright in the annals of science. Paul Ehrlich, famed for his researches on cancer and immunity, the latter based upon his theory of the chemical affinities of living cells, was the discoverer of a specific remedy for syphilis—salvarsan or "606", successful after 605 substances had been tried and failed! This remedy, a compound of arsenic, is now widely used in the treatment of the "red plague."

^{3a} This was the original method. It is now known that "antigen" a is non-specific. Hence extracts of various normal organs may be employed.

One of the most fatal diseases in days gone by was meningitis, caused by the bacterium *Diplococcus intracellularis*, which develops in the meninges or membranes surrounding the brain and spinal cord, setting up an inflammation resulting in death, or, if the victim is spared, often leaving paralysis, imbecility or some other dread condition in its wake. With the discovery of the causative organism some thirty years ago, biology set itself to find a remedy.

It is a well-known fact that both among men and lower animals there are many instances of natural immunity and susceptibility to disease. The native cattle of Austria-Hungary and Japan are relatively immune to tuberculosis, while other breeds are very susceptible. The Algerian sheep are comparatively immune to anthrax, to which all other sheep are extremely susceptible. Field mice are immune to glanders, while the house mouse is susceptible. The negro is more resistant to yellow fever and susceptible to tuberculosis than the white race. Malaysians are very susceptible to beriberi, while other races are much less so.

While some immunity to disease is thus "natural" or in-born, other immunity may be "acquired." After recovery from typhoid fever the subject is unlikely to have a recurrence of the disease for several years. The victim who has successfully withstood an attack of smallpox is thereafter usually protected against its ravages, while we are all familiar with the measles and whooping cough of childhood, which once experienced, give us comparative protection against further attacks. Modern theories and practice of immunity are of very recent date, and yet methods of immunity have been practised from an early date and by primitive people. The Chinese and other orientals were wont to protect themselves against smallpox by putting the scabs of patients into the nose of persons who had not yet taken the disease. In 1721 a similar method was introduced in England by Lady Mary Montague, and was practised there until the discovery of Jenner's method of vaccination. The Moors used to protect their cattle from pleuropneumonia by sticking a knife, which had been previously inserted in the lung of an animal which had died from the disease, under the skin of healthy animals. One of the tribes of central Africa, the Vatuas, are reported to immunize themselves against snake venom.

The various theories of immunity are too complex to be discussed in detail here, but the brief general statement may be made that immunity depends upon certain chemical substances in the blood which either aid in the destruction of bacteria or counteract the poisons which they produce (or both). The former process occurs in vaccination either with

a weakened (smallpox) or dead virus (typhoid fever); the efficiency of anti-toxins in diphtheria, and tetanus depends upon the latter, while meningitis serum acts both as a means of destroying the meningitis bacterium and of neutralizing the toxin produced by it.

But to return to the discovery of a cure for meningitis. For several years experimenters had been attempting to render animals immune to the disease, and then by injecting some of their blood serum into other animals to make these latter immune in their turn. Various species of animals were employed for this purpose, but the horse was the one finally selected, partly because normal horse serum, when injected into human beings produces no ill effects, and, partly for the reason that the horse is readily immunized against meningitis, and partly because of the large amount of serum obtainable from one animal. In immunizing a horse the first step is to secure the bacteria from some victim of the disease and grow them on some culture medium such as agar impregnated with beef bouillon and other nutrient materials. After a good growth has been obtained, the culture is scraped off from the agar and heated to 55° or 60° C. in physiological salt solution, to destroy the bacteria. A drop or two of this solution, containing the dead bacteria and some of their products, is then injected into a horse which has been kept under observation for some time and rigorously examined to determine its healthfulness. After eight days a second and larger dose is given and this is repeated at similar intervals for periods of from four months to a year, until the horse can withstand large injections, not of dead, but of living bacteria. The horse is then bled under aseptic conditions and the serum so obtained put in sterile vials and sent out to physicians for use.

The treatment with this serum was not at first successful however. The world-wide epidemic of cerebro-spinal meningitis beginning in 1904 stimulated the search for a remedy and these experiments were soon successful. The credit for the first successful use of anti-meningitis serum probably belongs to a European—Jochmann, but the principal development of the method is due to Flexner, working at the Rockefeller Institute in New York.

Early in his experiments Flexner employed monkeys as more likely than the lower animals to react to human diseases in a manner similar to men. By injecting cultures of the meningitis bacterium into the spinal column of monkeys Flexner infected them with the disease. Following these experiments he similarly employed intra-spinal injections of the curative serum, at first on monkeys and later on man, with

marked success, the comparative failure of the earlier experiments being apparently due to the fact that the injections were not made directly into the space surrounding the spinal cord, so that the anti-serum did not gain direct access to the seat of infection.

While the results with anti-meningitis serum are not perfect, they are nevertheless very encouraging. Whereas the mortality in the disease previous to the introduction of anti-serum treatment was about 75%, mounting in very young children to over 90%; in 1294 cases treated with the anti-serum the mortality was only 31%, and when the injection was given early in the disease this was reduced to 18%. Even more striking results have been obtained in the case of diphtheria anti-toxin, while in the use of vaccines as preventive agents the immunity secured is virtually perfect. The practically complete elimination of typhoid fever from our army in the recent war, and in the wild goose chase after Villa in 1917, is sufficient testimony to the effectiveness of anti-typhoid vaccination, while the prevention of tetanus in the wounded, when injected with anti-tetanus serum in time, tells clearly the story of the blessing of this remedy to man.

With the extent to which trench fighting was developed in the great war, men, with rats and like rats, burrowing and living underground in trench and "dug-out," came new diseases and we heard for the first time of "trench foot" and "trench fever." The first of these was clearly an individual infliction due to imperfect circulation caused by long standing in the wet. But the latter was apparently communicable, caused by some sort of micro-organism. Here was a new problem for biology to solve. Suspicion quickly fell upon the "cootie," and conviction soon followed. Twenty-two men allowed themselves to be bitten by lice from trench fever patients, as a result of which twelve of them acquired the disease; while four who were bitten by lice from healthy men did not contract it, and eight others living in the same quarters as the bitten men, but kept free from lice, also remained free from the disease, proving conclusively the guilt of the "cootie" as the carrier of infection.

In the field of protozoölogy, medical entomology and parasitology America has rendered conspicuous service both in discovery of new facts and in their application to human welfare. While the proof of the rôle of the mosquito in the spread of malaria is mainly due to English, French, and Italians, the extension of that proof to include the relation of the mosquito to the yet more deadly yellow fever is due to the devotion and courage of four young Americans (one a Cuban), as a result of which two of these suffered an attack

of the deadly scourge, and one of them (Lazear) laid down his life as a sacrifice to science and to mankind.⁴

The Italian Grassi and the Englishmen Low and Sambon had shown the necessary causative relation between the mosquito and malaria, and the relation between the distribution of yellow fever and the mosquito genus *Stegomyia*, led to a strong suspicion of the latter as the villain in the plot.

The demonstration of the theory was simple enough, but one requiring heroic self-sacrifice on the part of the demonstrators. The story has been so often retold that it may be passed over here in briefest outline. The theory of a causative relation between the mosquito and disease is not a new one. The very ancient literature of India contains suggestions of such a relation, particularly in regard to malaria. Many primitive peoples have had a dim idea that mosquitoes were to blame for the fevers prevalent in low-lying, marshy regions. The Mschamba tribe in Africa avoid such regions for fear of fever. In their language the same word (mbu) is used both for fever and mosquito. When Humboldt visited the region of the upper Orinoco he found that the natives attributed their fevers to mosquitoes.

As early as 1848 Dr. Nott of New Orleans suggested the mosquito as the transmitter of malaria and yellow fever, and in 1853 Beauperthuy published an article in the "*Gaceta Oficial de Cumana*" (Venezuela) in which he advanced a similar theory. Beauperthuy pointed out that yellow fever prevailed when there was a good mosquito crop. He suggested that the mosquito injected into the blood of its victims a poison which broke down the red corpuscles, mixing their coloring matter with the blood serum. This poison was obtained by the mosquitoes from decaying matters along the seashore or in swamps.

In 1881 Dr. Carlos Finlay of Havana, as the result of a careful and extended study of the life history and habits of the *Stegomyia* mosquitoes and their relation to yellow fever concluded that they were the agents in the spread of the disease, and in 1897 Dr. A. C. Smith of the U. S. Marine Hospital Service, tried an experiment at the national quarantine station on Ship Island in the Gulf of Mexico, which was a forerunner of the later work of our government in Cuba, and which strongly supported Finlay's conclusions. Dr. Smith completely screened the quarantine station where he had under treatment some thirty cases of yellow fever, taken from incoming vessels, and no new cases developed there.

The final and definite proof of the theory however was made

⁴Subsequently both Reed and Carroll died, probably as the indirect result of their work.

by a U. S. Army Commission appointed by Surgeon-General Sternberg in 1900, during our occupation of Cuba. The commission consisted of three Americans, with Walter Reed in charge, assisted by James Carroll and Jesse Lazear and a Cuban, Aristides Agramonte. Two well built houses were erected in the same situation, and fully screened. In one of these soiled bedding, brought direct from yellow fever patients in Havana, was placed, and here a number of men lived for several weeks without a single case of yellow fever developing among them. In the other house were two rooms separated only by a mosquito proof screen. One of these rooms was kept free from mosquitoes, while in the other were placed



CARROLL, LAZEAR AND REED

Members of the U. S. Yellow Fever Commission, which demonstrated the rôle of mosquitoes in the carriage of yellow fever.

Courtesy of the U. S. Bureau of Entomology.

mosquitoes which had bitten yellow fever patients. Among the men occupying the former no case of the disease developed, while one-half of those in the latter room developed the disease. In another experiment seven men were bitten by infected mosquitoes contained in a glass jar, and five of them contracted the disease. The subjects of these experiments were volunteers, members of the Commission themselves, U. S. soldiers and three Spaniards. Doctor Lazear died of the fever, as the result of an accidental bite by an infected mosquito. Dr. Carroll, contracted the disease, as the result of his experiments, and while he recovered from the fever, his death, four years later, was probably indirectly due to this attack. The first soldier who volunteered was John R.

Kissinger of Ohio, concerning whom Doctor Reed says in his report:

"I cannot let this opportunity pass without expressing my admiration of the conduct of this young Ohio soldier who volunteered for this experiment as he expressed it 'solely in the interest of humanity and the cause of science' and with the only proviso that he should receive no pecuniary reward. In my opinion, this exhibition of moral courage has never been surpassed in the annals of the Army of the United States."⁵ The Spaniards who volunteered did so for the money offered them, and because they had little faith in the theory. After three had contracted the disease however no more of them volunteered.

Let us look for a moment at a few of the results of these discoveries and sacrifices.

The failure of the French under DeLesseps to dig the Panama Canal was due to many factors, chief of which were dishonesty, extravagance and fever. With no knowledge of the causes of yellow fever and malaria it was naturally impossible for them to successfully combat these plagues. The exact mortality figures for the period of the French occupation are not available, but the rate is known to have been very high. The contractors who were doing the work for the Canal Company were charged \$1 a day for each of their men cared for in the company's hospital. Consequently when a laborer was taken sick his employer often discharged him in order to save hospital expenses, and many of these unfortunate men were left to die upon the roads leading into Panama and Colon. Of thirty-six Catholic nuns brought from France to serve as nurses twenty-four died of yellow fever. Seventeen out of eighteen young French engineers who came over on one vessel died within a month of their arrival.

When the United States undertook the canal work in 1904 Colonel W. C. Gorgas of the army medical corps was placed in charge of sanitation. The drinking water in the canal zone was almost entirely obtained from cisterns or water barrels. In the city of Panama alone there were four thousand breeding places for mosquitoes. These were immediately covered to prevent the entrance of mosquitoes, and in eight months' time there were less than four hundred receptacles containing mosquito larvæ. In addition to covering the rain barrels, about 700,000 gallons of oil were used for oiling pools, and nearly four hundred miles of drainage ditches cleaned out every year in order to destroy the breeding grounds and

⁵ Howard, "Mosquitoes of North and Central America," Carnegie Institution, Pub. 159, p. 244.

to kill the larvæ in those remaining. In order to ferret out every possible breeding spot more than 4,000 acres were cleared of grass and 2,000 of brush annually. And as a further protection against the remaining mosquitoes, and other insects, about \$1,000,000 were spent in screening residences, hotels and hospitals. As a result of this work "not a single case of yellow fever was contracted during the first two years under Doctor Gorgas, although there were constantly one or more yellow-fever cases in the hospital, and although the nurses and doctors were all non-immunes. The nurses never seemed to consider that they were running any risk in attending yellow-fever cases night and day in screened wards, and the wives and families of officers connected with the hospital lived about the grounds knowing that yellow fever was constantly being brought into the grounds and treated in nearby buildings. Americans, sick from any cause, had no fear of being treated in the bed immediately adjoining that of a yellow-fever patient. Colonel Gorgas and Doctor Carter lived in the old ward used by the French for their officers, and Colonel Gorgas thinks it safe to say that more men had died from yellow fever in that building than in any other building of the same capacity at present standing. He and Doctor Carter had their wives and children with them, which would formerly have been considered the height of recklessness, but they looked upon themselves, under the now recognized precautions, as safe almost as they would have been in Philadelphia."⁶

Similar results were obtained in Havana during the occupation of Cuba by the United States. Two "brigades" of mosquito fighters were organized, one to make war on the *Stegomyia* or yellow-fever mosquito in the city itself, and one on the *Anopheles* or malaria mosquito in the suburban district. The city was divided up into sections to each of which an inspector and two laborers were assigned, whose duty it was to see that all rain barrels were protected against mosquitoes, all cesspools oiled, and other receptacles of fresh water emptied. In the suburbs ditches and gutters were cleared of débris, new ditches dug where necessary, and the little puddles of water in the footprints of cattle or horses and other depressions in the field were drained, but little oiling being necessary.

Prior to the United States' occupation Havana was a pest hole and a serious menace to the health of our country. This condition indeed was one of the factors leading up to the Spanish-American War. In 1900 it was visited by a severe epidemic of yellow fever, deaths from which numbered 325;

⁶ Howard, *locus citatus*, pp. 431-2.

in 1907 as a result of the anti-mosquito campaign there were but 23 deaths, and the disease is now virtually unknown there.^{6a}

Within the United States anti-mosquito work has been sporadic and local in character, in many cases being undertaken privately rather than under national or state direction. Wherever it has been consistently pursued however it has given striking success. One of the most notable instances of this local work is that undertaken on Staten Island in 1901



WAR ON THE MOSQUITO

Filling in salt marshes with the contents of Brooklyn ash barrels.

Courtesy of the U. S. Bureau of Entomology.

by the New York Health Department under the direction of Dr. Doty, health officer of the port of New York. Staten Island is a long narrow island on the opposite side of New York Bay from the city, and between it and the Jersey shore a ridge of low hills forms the backbone of the island, with the land sloping down to salt marshes along the shores. Malaria has been epidemic there for many years, and its mosquitoes have been almost as famous as the New Jersey brand. The details of the work are similar to those already described, except that more extensive ditching operations were

^{6a} Noguchi has recently discovered a probable cause of yellow fever in the *Leptospira icteroides*. He has also devised a successful protective vaccine and a curative serum, which latter in several experiments reduced the mortality from 50% to 9%.

required in the drainage of the extensive marsh areas. The results were most gratifying. The *Anopheles* mosquitoes were virtually exterminated, with a consequent reduction in the number of malaria cases from thirty-three in 1905 to five in 1909,⁷ while other mosquitoes also have been greatly reduced in number.

But insects play not only a necessary rôle in the spread of disease; the incidental part which they take is on the whole far more dangerous than the other. In its discovery of this part biology has made one of its greatest contributions to human welfare. The trail of the fly has been followed so often and with such care in the literature of recent years that it seems superfluous to repeat what is so well known. And yet a few of the more striking facts concerning the relation of flies and other insects to the spread of disease, and especially the results of preventive measures may not be amiss; the more so since we still find in some quarters among supposedly educated and intelligent people an almost total disregard of the most common and fundamental laws of self-defense against disease.

While we are all sadly familiar with the reproductive capacity of the fly, probably few of us realize the theoretical possibilities of such increase—theoretical, because, owing to the inevitable loss of eggs and young, the possibilities are never realized. They are interesting and instructive however for if such possibilities exist theoretically, the realization must at least be very great. A fly lays on the average 120 eggs at one time, which come to maturity in ten days, and in the latitude of Washington, D. C., there may be as many as twelve broods in a season. If every other egg of every brood gave rise to a fertile female (assuming an equality in the number of males and females) and this in turn produced broods of its own in due season, one mother fly would produce 2,568,034,296,513,029,664,000⁸ flies, which if strung end to end on a thread would reach some 400,000,000,000 times around the earth.

The fly's body is clothed with fine hairs and a single fly has been estimated in some cases to carry more than 6,000,000 bacteria.

In 1898 there were concentrated in army camps in the South thousands of men gathered there for our campaign against the Spaniards in Cuba. These men ate in unscreened mess halls near which were the similarly unprotected latrines of the camp, affording free passage for the millions of flies

⁷ Prior to 1905 there are no satisfactory data on the number of cases.

⁸ Computed by E. F. Chandler, Professor of Civil Engineering, University of North Dakota.

which swarmed from latrine to mess table. Typhoid fever developed in the camp and the resultant roll of 22,420 cases and 1,924 deaths told all too plainly the work of the fly as the agent of death. Bacteriological examination of the bodies of flies confirmed the evidence of the sick list, showing beyond peradventure the responsibility of the fly. Contrast this with our record in the recent war. In the army camps an almost entire absence of flies, even though nearby towns and villages were furnished with an ample quota, no uncovered garbage piles, loose refuse, or unscreened mess halls and kitchens; no poorly built and unsanitary toilets, no dirty streets and ill-scrubbed floors. A returned soldier put the situation in a nut-shell when he said that he wished every civilian could have a dose of sanitary training in the army. And the result? A reduction of the death rate from all diseases, prior to the influenza epidemic in 1918, to less than one-half that of the healthiest part of the United States. This epidemic levied a terrible toll upon the crowded army camps, serving to illustrate man's utter helplessness in the face of an enemy who fights with unknown weapons.

As a further specific example of the results of the "swat-the-fly" campaign in America, when consistently carried out, let us take the experience of Wilmington, N. C., in 1911. During the summer of this year all manure piles and other possible breeding places for flies were several times sprinkled with pyroligneous acid to destroy the developing eggs and larvæ. The result of this work is shown in the accompanying table in which + indicates the time of sprinkling.⁹

Typhoid Cases		Date of sprinkling with pyroligneous acid
June 1-7	11	
8-14	22	+
15-21	50	+
22-28	42	
29-		+
July 5	10	
6-13	11	
14-20	3	+
21-	0	

In 1907 the Merchants' Association of New York City appointed a committee to study among other things the work

⁹ From Stockbridge, "How to Make a Flyless Town," *World's Work*, vol. 24.

of the fly in spreading disease. Their findings showed that where the sewage was thickest there the flies were most abundant and further that the number of deaths from various intestinal diseases corresponded very closely to the abundance of flies from week to week.

A similarly incidental rôle in the spread of the dread bubonic plague has been traced to the rat and its boon companion, the flea. While the plague is a native of the East, its ravaging march has often extended over Europe and it has even crossed the Pacific and visited our shores.

The rôle of the rat in the spread of plague was suspected by the ancients centuries before the Christian era. Samuel tells us that in one of the numerous wars between the Philistines and the Israelites, the former made off with the national emblem of the Hebrews, the Ark of the Covenant; whereupon as a sign of His displeasure the Lord visited upon the thieves a scourge of plague. To assuage the wrath of the offended Deity the priests of the Philistines told them to return the stolen goods and to make a peace offering to the Lord of "five golden images of the emerods (boils) in their secret parts, and five golden images of the mice (rats?) that marred the land."¹⁰

The early Greeks recognized Apollo as the sender of the plague and the mice (rats?) as his messengers. During the reign of the Roman Emperor Severus a great epidemic of the plague broke out in Asia Minor. A coin made at Pergamos at this time shows on one side an image of the god of medicine Æsculapius, with a dead rat at his feet and by his side a naked human figure in an attitude of supplication.

Since the days of Justinian down to recent times the plague or "black death" of the Middle Ages has swept repeatedly over Europe leaving death and desolation in its trail. "Truth is indeed stranger than fiction" and neither the "Rienzi" of a Bulwer nor the "Romola" of an Eliot has outdone, in their wonderful pictures of the pestilence which overwhelmed Italy in the fourteenth century, the colorless facts recorded by history. From time immemorial plague appears to have been of frequent occurrence in Asia and Africa, but only in recent years has it invaded the western hemisphere. The outbreak in San Francisco in 1905 brought home forcibly to Americans the truth that in these days of rapid and easy communication between our own shores and those of Asia we are living not to ourselves alone, but are in truth our "brother's keeper." With the opening of the Panama Canal and consequent shortening of the voyage between the orient and our Gulf and Atlantic ports, the

¹⁰ I. Samuel, vi, 5.

danger of an occasional recurrence of the disease among us becomes still greater.

Without the aid of biology we should still be living in the Dark Ages so far as plague is concerned. With the discovery of the bacillus causing the disease in 1894 it was shown that mice, rats, guinea pigs, rabbits, monkeys and many other animals can be infected by inoculation as well as by feeding with infected material. But how was the disease transferred from man to man? Was it a "miasma" or foul air which did the damage? Was it by "fomites" or infected clothing and other articles that contagion was spread? Or was personal contact necessary for infection? Here enters the ubiquitous flea. The Indian Plague Commission appointed by the British Government to study the scourge in India found that it was only in the presence of fleas that contagion was spread from one animal to another. Young rats may even be suckled by plague-infected mothers without contracting the disease, provided fleas are absent from their cages. Rats and guinea pigs may be kept healthy in cages hung in rooms where animals have recently died of plague. But if the cages be hung near enough to the floor to permit the fleas to jump in, they become infected. On the other hand the cages may be placed upon the floor without danger of infection, provided only they be surrounded with "tangle foot" thereby preventing ingress of fleas. Furthermore contagion may be spread through the transfer of fleas from infected to healthy animals without any contact between the latter. In the light of these experiments proof appears to be conclusive that the flea is the most important, if not the only direct intermediary in the spread of plague.^{10a}

But the flea does not confine his attentions to rats alone. He believes in a varied diet, and an occasional meal of human blood is quite to his taste. Consequently in rat-infested and dirty dwellings, where fleas abound, if plague breaks out among the rats, their human co-habitants are almost certain to be stricken likewise.

Previous to 1900 plague had never occurred in the United States although it had visited Mexico and South America. In this year there was an outbreak of plague in "Chinatown" in San Francisco, followed in 1907-8, a year after the great earthquake and fire, by a second outbreak, in both of which there was a total of 281 cases and 85 deaths. When the disease was discovered the city authorities at first adopted the ostrich policy and endeavored to suppress all information relative to it.

"In San Francisco plague met politics. Instead of being confronted by a united authority with intelligent plans for

^{10a} Pneumonic plague may be transmitted direct by the breath.

defense, it found divided forces among which the question of its presence became the subject of factional dispute. There was open popular hostility to the work of the sanitarians, and war among the City, State, and Federal health authorities.

"A federal health officer was arrested for trying to do his duty as he saw it. Eugene Schmitz, while mayor, refused to approve the printing of health reports and vital statistics and attempted to remove from office four members of the Board of Health who persisted in the statement that plague existed in the City. The State bacteriologist, Ryfkogel, found plague germs and lost his position and part of his back salary.

"The public drew its inferences from the voluminous misinformation furnished by the disputants. Plague was said to be a mediæval disease. It belonged to the days of Charlemagne or James II before the common people had soap. It was an Oriental disease, peculiar to rice-eaters. It was a Mongolian or Hindu disease, and never attacked whites. In San Francisco it was not a disease at all—it was graft. Landlords of Chinatown rat warrens contended fiercely that their premises were perfectly sanitary because the plumbing was vented.

"For a while the people were in the gravest danger and it seemed impossible to convey any adequate warnings to them. Intimations from medical conventions of Eastern State boards of health that unless San Franciscans got together and stamped out the plague, it would be necessary to enforce a general quarantine against the City, actually brought forth a demand from certain quarters that the Marine Hospital fellows go back to Washington where they belonged."¹¹

Without the necessary power to act in the case the local health authorities called upon the U. S. Public Health Service, with the result that Doctor Rupert Blue was placed in charge with full authority to act. Doctor Blue immediately instituted a relentless war upon the rats which infested the city, with the result that the disease was soon entirely eradicated. As illustrative of the rôle of the rat in the spread of plague in San Francisco the following data are quoted from Doctor Blue's reports.

"Two small boys (October, 1907) while playing in an unused cellar found the body of a dead rat. The corpse was buried with unusual funeral honors. In forty-eight hours both were ill with bubonic plague. A laborer finding a sick rat on the wharf picked it up with the naked hand and threw it into the bay. He was seized three days later with plague. Doctor C. and family lived in a second-story

¹¹ "Eradicating Plague from San Francisco," Report of the Citizens' Health Committee, pp. 30-31.

flat over a grocery store in the residence section. Being annoyed for some days by a foul odor the doctor caused the wainscoting around the plumbing to be removed. One or two rat cadavers were found in the hollow wall. In two or three days the two members of the family who used the room sickened, one dying on the fifth day of cervical bubonic plague. It is probable that infected rat fleas were set free by the removal of the wainscoting. Dead rats were frequently found in or near houses where plague had occurred."¹²

An outbreak of plague in rats occurred in New Orleans in 1914. As the result of prompt measures for the destruction of rats and the fumigation and rat-proofing of the infected premises the disease was suppressed with but a single case occurring in man.

An effective piece of plague control work is that conducted by the Bureau of Health in the Philippines. The method of plague control practised in Manila is of interest as showing how it is possible practically to suppress the disease even though it may be impossible to completely exterminate the rat.

"A list of the places at which plague-infected rats were found was made. Each was regarded as a center of infection. Radiating lines, usually five in number, were prolonged from this center, evenly spaced like the spokes of a wheel. Rats were caught along these lines and examined. Plague rats were seldom found more than a few blocks away. The furthestmost points at which infected rats were found were then connected with a line (and) the space inclosed by the dotted line was regarded as the section of infection. The entire rat-catching force, which had heretofore been employed throughout the city, was then concentrated along the border of the infected section; that is, along the dotted line. They then commenced to move toward the center, catching the rats as they closed in. Behind them thorough rat proofing was carried out. One section after another was treated in this way until they had all been wiped out. Once weekly thereafter rats were caught in the previously infected sections and at other places which were insanitary and which had been infected in years gone by. This was continued for one year."¹³

But not alone is the rat responsible for the spread of plague. At least two species of ground squirrels as well as the tree squirrel have been shown to be susceptible to the plague bacillus, and the occurrence of plague in the first of these has been shown in nature, as well as its probable relation to the

¹² "The Rat and Its Relation to the Public Health," p. 147. The U. S. Public Health Service.

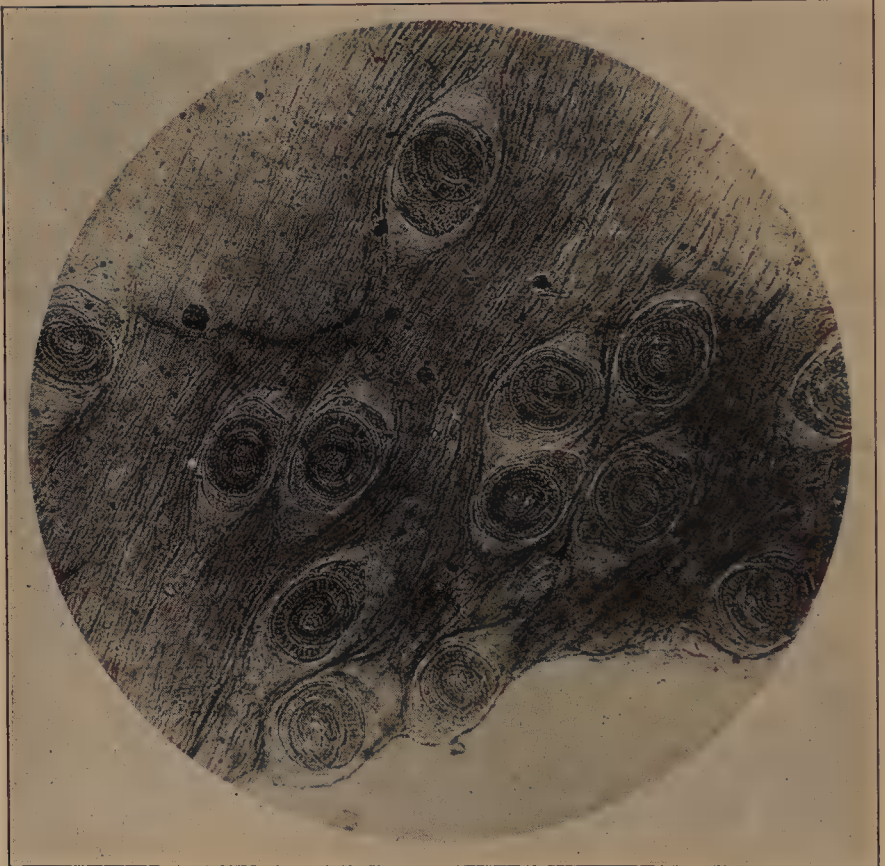
¹³ *Locus citatus*, pp. 205-6.

occurrence of the disease in man. In 1904 a case of human plague occurred a short distance east of San Francisco, and in 1906 a boy near Oakland was attacked by the disease after handling some ground squirrels which he had shot a few days previously. In July, 1908, two cases of human plague were found in the same region in California, and an examination of 425 ground squirrels collected in the vicinity showed the presence of the disease in four. In August of the same year a boy was stricken with plague in Los Angeles after being bitten by a sick ground squirrel, and a dead squirrel taken in the vicinity was found to be infected with plague. The woodchuck has been suspected as a plague spreader, but its relation to the disease has not been proven as yet.

Not only are ground squirrels a source of danger in the spread of plague, but the loss they cause in the destruction of grain is very serious. Their destruction therefore is of first importance for both sanitary and purely economic reasons. To the accomplishment of this task both the U. S. Public Health Service and the Biological Survey are devoting their energies. Many methods are employed at present for the extermination of both rats and ground squirrels, which have been discussed in a previous chapter. In the destruction of rats, trapping, poisoning, inoculation with viruses or bacterial cultures, shooting and rat-proofing have all been employed more or less successfully. Space does not permit a detailed discussion of the use and merits of these various methods, but it may be said in a general way that the rat-proofing of buildings and systematic trapping are the most effective means of control.

There are many diseases of man and lower animals, some of them among the worst scourges of the human race, which are caused, not by microscopic organisms, either plant or animal, but by parasitic worms. One of the most terrible of these diseases is trichinosis, caused by a minute worm, about 1/20 inch in length, the *Trichina spiralis*. The devastations of this disease have been greater among some of the poorer classes of Europeans, who were accustomed to eating raw pork, than among Americans. Nevertheless the disease is not unknown in this country, and the occasional occurrence of the parasite in American hogs led about 1880 to the prohibition of their import into several European countries. The worm is a parasite of man, the hog and the rat, its life history being similar in each. Let us trace this, starting with a pair of adult worms living in the intestine of the hog. Here the female is fertilized and gives birth to some thousands of progeny, which promptly bore their way through

the wall of the intestine, and then migrate, probably through the blood vessels to the muscles. Here they encyst, surrounding themselves with a capsule which is partly secreted by themselves and partly by the irritated tissue surrounding them. If now, the improperly cooked flesh of a hog, infected with these trichinae is eaten by man or the rat, the sheaths are dissolved by the digestive ferments of the second host and the



TRICHINA IMBEDDED IN MUSCLE

Courtesy of the U. S. Bureau of Animal Industry.

worms are set free in its intestine to repeat the cycle occurring in the hog. It is during the course of their migration and encystment in the muscles that occurs the terrible suffering caused by this disease which is usually relieved by death alone. If however the infection be light, the patient may recover, the worms finally dying, and being absorbed, leaving only the connective tissue scars to mark their place. Since hogs rarely have the opportunity of eating human flesh the rat becomes in one sense a necessary agent in the persistence

and spread of the disease. There is no remedy known, save that of prevention, and it is here, in the safeguarding of our meat supply that the protecting hand of Uncle Sam is stretched forth to save both the lives and the dollars of his children.

Other parasitic worms of occasional occurrence in the United States but of minor importance from a medical standpoint, because of their relative benignity, are the tapeworms transmitted to men in the flesh of both hogs and cattle.

The story of the tapeworm briefly told is as follows: This is as its name implies, a tape or band-like animal, divided into segments which become progressively larger and riper in



A TAPE WORM OF MAN

Courtesy of the U. S. Bureau of Animal Industry.

passing from the "anterior" or "head" end posteriorly. The beef tapeworm lives in the intestine of man, and its ripe proglottids are passed in the stools of the patient. These cast proglottids are virtually nothing but a sack full of embryos, each surrounded by a horny shell. If one of these embryos is taken by the beef in its food or water, it loses its shell in the beef's stomach and passes into the intestine as a tiny embryo about $\frac{1}{80}$ of an inch in diameter. This is armed with three paired hooks by means of which the larva rapidly works its way through the intestinal wall and into the blood vessels, through which it is carried to the muscles or "flesh" of the animal where it grows to a considerable size, acquiring the "head" or attachment organ of the adult worm. The larva

now consists of a sack-like bladder filled with fluid, which has given this, and similar larvæ the name of "bladder-worm," inside of which is the head in an inverted position like the inturned finger of a glove. In the muscles the larva is surrounded by a connective tissue sheath similar to that surrounding the *Trichina* larva already described. If a piece of improperly cooked beef containing one of these larvæ is eaten by man, the "bladder-worm" loses its "bladder," turns its "head" inside out, thus bringing it into the proper position for a frontal attack on the intestine of its host, to which it attaches itself by means of four "suckers" on its "head," and now proceeds about its business of growing and producing ripe segments, which may in their turn infect another beef.

For the benefit of those who enjoy a nice juicy piece of rare beefsteak it may be said, that with the very efficient inspection service of the U. S. Bureau of Animal Industry the occurrence of tapeworms in this country is decreasing, and meat coming from an inspected slaughter house may be eaten with impunity. This of course does not apply to meat slaughtered by country butchers.

Living in our Southern States is a community of people called with contempt by negroes and whites alike the "po'-whites." They are a shiftless, lazy lot of "ne'er-do-wee's" living in utter disregard of health or decency. Many of them have never been to school, and those children who do go to school stand from forty to ninety points lower on a scale of one hundred in their ability to improve, than their comrades. They are found in rural communities and the smaller towns and villages wherever unsanitary living conditions occur. In Porto Rico about ninety per cent of the poorer inhabitants are of this type. Many of them are what are known as "dirt eaters," rivaling even the traditional goat in their fondness for paper, old rags, earth, lime, etc. For generations these people have presented an insoluble problem to physician and philanthropist alike. Was the cause of their condition hereditary? Had some outcast from the slums of Europe escaped to America with the early settlers and peopled the South with his degenerate progeny? Or was the hard environment too heavy a handicap for them to overcome? Was weak mentality and feebleness of purpose to blame, or yet was the cause a physical one, some insidious disease which inappreciably, yet none the less certainly was sapping the energy, both mental and physical of its victims?

The answer to these questions came to us indirectly from Europe. In cutting the St. Gothard tunnel through the Alps it was observed that many of the miners who were bare-

footed were anemic, run down and unable to do good work, and the Italian Perroncito at that time traced the disease to the hookworm *Ankylostomum duodenale*. Some years later the German Looss, traced the course of the worm from the infected soil to the intestine of its victim by a very clever bit of biological detective work. There had been known for many years an irritation of the skin of the feet under the names of "ground itch," "foot itch," "dew itch," etc.



(a) FEMALE, (b) MALE, AND (c) MOUTH OF THE HOOKWORM

An animal which is mainly responsible for the condition of the "poor whites" in the South, and which causes an economic loss of perhaps \$500,000,000 annually. The disease can be effectively and easily cured, while its prevention is merely a matter of a few simple sanitary precautions. (After Stiles.)

"While experimenting with hookworm larvæ he spilled some of them on his hand; he noticed a burning sensation and in a few minutes the larvæ had disappeared. After the proper interval, about two months, he found himself suffering with the hookworm disease. To determine what had become of the larvæ that were spilled on his hand he poured some larvæ on the leg that was about to be amputated from a boy; on sectioning the skin of this leg, after amputation, he found the larvæ had worked their way through the skin

by way of the hair follicles, sweat ducts, etc. To follow the further course of the larvæ he placed some of them on the skin of a number of dogs which were killed and examined at various intervals. In this way he worked out the entire course of the larvæ from the skin to their final resting place in the intestine."¹⁴

Where a number of poor and ignorant miners were collected in narrow underground quarters, as in the building of a tunnel, with no proper arrangements for the disposal of bodily wastes, it is plain that the most elementary rules of health would be disregarded and that filth would abound.

The hookworm derives its name from the slightly bent or hooked anterior end. In the mouth are four hooks and two conical teeth by means of which it attaches itself to the mucous membrane of the intestinal wall. Here it is said to live for several years, during which time it produces an enormous number of eggs. If these chance to be deposited in a moist place, as in the pools of water in a mine or tunnel, they hatch into larvæ which live in the water or moist earth until they meet the bare skin, usually of the feet, of another victim. They then bore through the skin into the blood vessels where they are carried by the blood stream to the heart and finally to the lungs. Here they leave the circulation, enter the lungs, and crawl into the bronchial tubes, up which they crawl to the throat and thus reach the œsophagus. From here they pass through the stomach to the intestine. The hookworm may also reach the intestine directly in unwashed fruit or raw vegetables.

Knowledge of hookworm disease and the part it plays in deteriorating so large a proportion of our southern population is mainly due to Dr. Charles W. Stiles, the parasitologist of the U. S. Public Health Service. Stiles has studied the disease extensively in the South and found the cause to be the same as in Europe although the American worm is somewhat different from its European cousin. Stiles' researches, aided by the liberality of the Rockefeller Foundation, and by the activity of state boards of health throughout the South, have made widely known the cause, and means of prevention and cure of the disease. The abolition of the unsanitary privy on the one hand, and thymol and epsom salts on the other, will rid the world of a scourge infesting an area in which live about 1,000,000,000 people, or more than half the total population of the world, with an infection rate in some countries as high as ninety per cent among the labor-

¹⁴ Reese, "Economic Zoölogy," p. 35. By permission of P. Blakiston's Son and Company.

ers, and causing an economic loss in sickness and death of untold millions.

The announcement by Dr. Stiles of the part which the hookworm was playing in undermining the mental and physical health of multitudes of people in the South, in causing incalculable financial loss and retarding the development of the country, was at first greeted with amusement or indifference, followed by active hostility. He at once became the subject of the usual campaign of the newspaper reporter and cartoonist, which greets every innovator, especially in an unprogressive and conservative community. In an early conference at Raleigh, N. C., "an incredulous physician in the audience asked him if the disease existed there. 'I see several pronounced cases in the room now,' he replied. A local newspaper declared that the Commission was slandering the community; the Governor gave out an interview in praise of the health of the fair land that he ruled over and denouncing its slanderers. Sketches of the lives of aged men of the neighborhood were published, to prove the healthfulness of the community, and much other such nonsense and ignorance was put forth."¹⁵

The opportunity for service in the fight against the hookworm was early brought to the attention of Mr. John D. Rockefeller, and the result was the organization of the Rockefeller Hookworm Commission in 1909. Briefly the work of this Commission, in co-operation with state boards of health throughout the South, has been the establishment of traveling dispensaries for treating the sufferers and educating the people in general regarding the danger, prevention and cure of the disease. The following quotations taken from the Commission's report for 1911 illustrate better than mere figures what the Commission has done in its service to the South.

"When the work began two years ago the people did not know hookworm disease as a disease. The announcement of its prevalence they had not taken seriously. It was extremely difficult to induce them to be examined, and even more difficult to get them when found infected to consent to treatment. The physician could not treat them until they had been shown that it was to their interest to seek his aid. For two years systematic effort has been made to give them the facts. The educational activities outlined in the report for last year have been persistently pursued in each State; the people have been taught by public lectures with charts and lantern slides, by bulletins and folders, by the public press, by exhibits at State and county fairs, by the examina-

¹⁵ "World's Work," Vol. 24, p. 505.

tion of children in the schools and students in the colleges, by examinations made at the State laboratories, by the celebration of public-health day; and most effective of all has been the teaching of the people by demonstration through the treatment of large numbers at the county dispensaries. . . . At times the clinics are small when the dispensaries are new or in communities where the infection is light; but in communities where the infection is heavy and after the dispensary has had a few days within which to demonstrate its effectiveness, the people come in throngs; they come by boat, by train, by private conveyance for 20 and 30 miles. Our



A HOCKWORM DISPENSARY IN KENTUCKY

The people travel for miles to obtain treatment.

Courtesy of the Rockefeller Foundation.

records contain stories of men, women, and children walking in over country roads 10 and 12 miles, the more anemic at times falling by the way, to be picked up and brought in by neighbors passing with wagons. As many as 455 people have been treated at one place in one day. Such a dispensary group will contain men, women, and children from town and country, representing all degrees of infection and all stations in life. A friend who had just visited some of the dispensaries said to me recently: 'It looks like the days of Galilee.'

"The people usually begin to arrive early. I visited one dispensary at 8 o'clock in the morning and found 43 persons there waiting for attention. They linger; they gather

in groups around the tables of exhibits; they listen to the stories of improvement as told by those who have been treated, and return to their homes to report to their neighbors what they have seen and heard. . . . The effect of these educational activities is seen first of all in the transformation which has been wrought in public sentiment. This change of sentiment shows itself in the co-operation of the press—which is now practically universal in all the States—in the growing co-operation of the physicians, of the educational agencies,



THE RESULT OF HOOKWORM TREATMENT

(Left)—A victim of hookworm.

(Right)—The same girl after treatment.

Courtesy of the Rockefeller Foundation.

of the whole people; it shows itself in an increasing support, not only of this particular work, but of all public-health interests."¹⁶

Probably in no field of medico-biological research have animals played a larger part than in the investigation of cancer. Rats and mice have been the principal subjects for these experiments, because of the readiness with which cancerous and other growths can be transplanted in them, and

¹⁶ "The Rockefeller Sanitary Commission," Second Annual Report, pp. 17-22.

because of their small size, fecundity and the ease with which they can be reared in captivity. Many other animals however have been employed, including the long-suffering guinea pig, dog, cat and chicken.

The study of cancer dates back into far antiquity. The early Greek and Roman physicians, Hippocrates, Celsus and Galen, thought of diseases as due to a disproportion in the amount of the four cardinal "humors" of the body—the blood, mucus, yellow bile and black bile. Cancer was fancied as caused by an excess of the latter, while even as late as 1874 the noted English surgeon and pathologist, Sir James Paget, ascribed cancer to a morbid condition of the blood. At the beginning of the seventeenth century one writer put forth the view that cancer was caused by a spirit (the Archeus) resident in the stomach and spleen. Unless this spirit was purified it was apt to intrude itself into parts of the body where it did not belong, thereby producing cancer.

Green frogs have been associated with cancer in the minds of the credulous for hundreds of years, and Bonet of Geneva in 1682 gave a formula for a cancer ointment made of green frogs, while in a book published recently (1905) in South Africa occurs the following interesting item (as translated): "An example of a woman who had cancer of the breast, which was already so severe that eight holes had been eaten into it, and who recovered through the following expedient: She took eight frogs applied to the breast in a muslin bag, which attached themselves instantly thereto as firmly as leeches. When they had sucked to repletion, they dropped off in violent convulsions without the sucking causing pain. This was repeated until 20 frogs were used, which all from time to time, sucked until they died. And the breast was not only cured, but returned again to its normal size absolutely." Another remedy of the same author is tortoise liver "laid on the cancer and used continually."

About the beginning of the seventeenth century one healer put forth the following receipt which he asserted from certain experience to be excellent for "ulcerous cankers." "Take suckling Puppies, put them in Wine, and distill it half off in Balneo; then take the puppies out, and boil them in a sufficient quantity of Golden-Rod Water, or common Water with Golden-Rod in it; when the Decoction is made, add the Water that was distilled off the young Dogs and boil them together till the flesh comes from the Bones. Then distill them all in Balneo. Keep the Water for use. Wet dry clothes or rags in this, and apply it to the ulcerous carcinoma. For from certain Experience it heals the sore by cleansing and drying."

"Since the beginning of recorded medical history, and doubtless before, imagination was given full play in the treatment of cancer. The 'witch doctor' combined the secrets of the 'black art' with the brewing of the 'witch's broth,' and the unfortunate victim of cancer was given doses of the mixture. Throughout the centuries the sufferer from this disease has been the subject of almost every conceivable form of experimentation. The fields and forests, the apothecary shop and the temple have been ransacked for some successful means of relief from this intractable malady. Hardly any animal has escaped making its contribution, in hair or hide, tooth or toe-nail, thymus or thyroid, liver or spleen, in the vain search by man for a means of relief. The hand on the dial has turned many times to the same point of effort during the progress of the centuries, and it is possible to find in remote districts today the same remedies being used that were employed by 'cancer curers' of long ago."¹

Apart from these early fancies what we may call the modern theories of cancer have been many and varied. We know that its immediate cause is an unlimited growth of certain epithelial cells which run riot in the body, encroaching upon and finally destroying the other tissues and producing death. But what it is which causes this growth we do not know. It has been supposed to be the result of the growth of a wandering germ cell which has become misplaced and undergone a sort of parthenogenesis within, rather than without the body. In this connection the observations of Professor Allen of the University of Kansas on the germ cells of certain fish, Amphibia, reptiles and mammals are of interest. Allen found that the primitive sex cells in these animals instead of arising in the sex glands appeared first in the wall of the gut, whence they wandered into the ovary, where they experienced their final development. It is quite conceivable that such a wandering germ cell might "get lost" in its migrations, and finding itself in strange surroundings, develop abnormally, producing a cancer.

Closely related to this theory is that which explains cancer as the result of the type of division of epithelial cells which characterizes the germ cells at a certain stage of their development, and which is explained in Chapter VII dealing with the physical basis of Mendelian inheritance. Yet another theory of somewhat similar character, proposed by the late Professor Boveri, the noted German cytologist, relates cancer to some abnormal type of cell division in which the chromosomes become misplaced and unevenly distributed

¹ Above quotations from Bainbridge, "The Cancer Problem," pp. 2-3. By permission of the Macmillan Company.

to different cells. Respecting this theory, it may be said that while there undoubtedly is abnormality of cell division in cancer, it may more likely be its result rather than its cause. Still another hypothesis attributes cancer to some parasitic organism presumably bacterial, of which many have been described by enthusiastic investigators, but none proven.

Finally we have the explanation of cancer as due to chronic irritation of some part of the body, stimulating abnormal cell growth of that region. There is much more evidence for this than for any of the preceding theories. One of the most frequent locations of cancer is the milk gland, an organ which is apt to be under continual irritation from an ill-fitting or tightly laced corset. In smokers the tongue and lip are frequent sites of cancer, regions apt to be irritated by the pipe stem or cigar. Cancer of the abdomen is prevalent among the natives of Kashmir who carry small earthen jars, surrounded by basket work and containing a charcoal fire, under their robes next to the skin as a means of warmth.

That cancer is inherited in mice has been recently claimed by Miss Slye of the Otho S. A. Sprague Memorial Institute of Chicago, as the result of an extensive series of breeding tests; and her results have been apparently accepted by some members of the medical profession. They lack substantiation however and it would be well to travel slowly over a path so newly blazed into the unknown, lest we stumble and fall into error on our way.

The past twenty years have witnessed remarkable developments in the study of cancer in both America and Europe. This study has been conducted both in the clinic and the laboratory. At present its net result is a negative one. It has served to explode many promising theories of cancer, and to reveal our ignorance, but as yet we are still fighting blindfold one of the most terrible enemies of man.

In America this work was instituted in 1898 when the State of New York made a small appropriation for cancer research at the University of Buffalo. Since 1901 the laboratory at Buffalo has been known as the Cancer Laboratory of the New York State Board of Health. The following year saw the inauguration of the Cancer Commission of Harvard University, whose work is conducted jointly in the laboratories of Harvard University and in the Collis P. Huntington Memorial Hospital of the same institution.

These initial undertakings have been followed by many others, such as the Research Department of the New York Skin and Cancer Hospital, the George Crocker Special Research Fund of Columbia University, the Barnard Free Skin and Cancer Hospital of St. Louis, and the Research Hos-

pital of the New York State Institute for the Study of Malignant Disease.

Cancer-like growths are of frequent occurrence in animals other than man. Rats and mice are especially prone to have them, but they are also known in dogs, cats, horses, mules, asses, cattle, hogs and in a host of wild mammals. Among birds they occur commonly in chickens and have been reported in others, both wild and domestic. They have been noted in various reptiles and amphibians, while artificially reared fish are especially susceptible.

Great as is our ignorance regarding many of the scourges of mankind, the advances in our knowledge in the last fifty years have been phenomenal, and the promise of the future was never so bright.

By what means have these revolutionary advances in our knowledge of disease been made possible? Chiefly by experiments on animals. Bacteriology has developed methods peculiar to itself and the development of these methods has been possible only through animal experimentation. When the bacteriologist announces the discovery of a "germ," as causing some disease, it is only after putting his new find through a long series of experiments, which demonstrate conclusively its relation to the disease in question. First, it must be found consistently in the bodies of patients afflicted with the disease. Second, it must be isolated from such patients and a "pure culture" in some culture medium (gelatine, broth, etc.) obtained. Third, it must be possible to infect some animal with this culture, and thereby produce the disease in it. Fourth, the same germs must be found in the infected animal. Fifth, from this animal a pure culture must be obtained with which the disease can be reproduced in another animal, and this cycle must be repeated with sufficient frequency to prove that the relation between the germ and the disease is a necessary, and not merely accidental one. Sixth, no other germ tested in the same way must give similar results.

Without experiments on animals most of these results would have been impossible, and yet there are today many seemingly rational people, who would restrict the use of animals for the saving of human life, and alleviation of human misery, under the specious plea of preventing suffering—to animals!

In whose hands is the administration of this new knowledge? Who are responsible for safeguarding the nation's health? Many are the agencies involved in this great work and many the objects of their care. International, national, state and local in scope; public and private in support;

philanthropic and commercial in purpose, the character of these agencies is as varied as are the objects of their concern. Space forbids any adequate consideration of them all, but we may glance for a moment at the work of one or two, which are broadest in scope and foremost in accomplishment.

When we are enjoying our roast beef or leg of mutton, how often do we stop to consider the care which Uncle Sam takes to insure our safety in partaking thereof? At every slaughter-house and packing plant engaged in interstate trade the U. S. Bureau of Animal Industry maintains inspectors whose duty it is to prevent diseased meat from entering into this commerce. When the animal arrives at the slaughter-house it is examined "on the hoof" before butchering, and if passed separate examinations are made of neck glands and viscera, and finally, if the animal passes muster, the meat itself when cleaned and dressed is inspected, and the government's approval is stamped upon it, before it enters refrigerator car or room preparatory to shipment and sale.

In the preparation of the many biological remedies on the market today, such as vaccines, antitoxins and glandular extracts of various sorts (pituin, thyrotoxin, adrenalin, etc.), yet greater care is exercised to guard against contamination of any sort. All establishments preparing such materials for interstate commerce must obtain a U. S. license before the government will permit them to do business. Before granting such a license an inspection is made of the premises where the work will be done by an agent of the U. S. Public Health Service. Such inspection is repeated at intervals to see that the plant is up to standard, and the products themselves are tested for purity (both chemical and biological) to determine their efficiency and safety.

As an illustration of the care which is taken to safeguard the user of these products, let us follow for a moment the method of preparing one of them, namely, smallpox vaccine. This vaccine is the pus which forms in little pustules on cattle infected with cowpox. The animals used in its preparation are usually young bulls or heifers. These are quarantined for several weeks, during which time they are carefully inspected for any possible disease and tested for tuberculosis. If found healthy they are given a careful scrubbing with soap and water, and some weak antiseptic and then taken to the vaccine laboratory. The operating and propagating rooms are constructed with a view to the utmost cleanliness, the floors being of concrete and the walls and ceilings enameled. The interiors and fittings are washed at frequent intervals with disinfectants. In the laboratory the animal is placed on a special operating table, the abdomen

shaved, washed with sterile water, and cut in a series of parallel lines with a sterile knife. Into these cuts the virus, taken from another animal under aseptic conditions, is introduced with a sterile instrument. The animal is now placed in the propagating room, where an attendant is at hand night and day to keep the room in the cleanest condition possible. After about a week, when the characteristic pox pustules have developed, the animal is killed, its abdomen washed with sterile water, the pus removed with a sterile instrument and placed in 50% glycerine in a sterile vessel which is then placed in a refrigerator.

The carcass of the animal is examined and the vaccine is tested for any possible contamination by inoculation of guinea pigs and culture media. Its efficiency is tested by trial vaccinations of calves, rabbits or guinea pigs. If found to be both pure and potent it is placed in small, sterile glass tubes, or on ivory points, which are sealed in sterile glass containers, labeled, dated and returned to the refrigerator until ready for the market.

The activities of the U. S. Public Health Service cover practically every phase of the nation's health. From guarding our ports against the entrance of infection with its quarantine service, to examination of rats and mice for plague bacilli at Seattle and New Orleans, or ground squirrels in California, the Service is waging a nation-wide and relentless warfare against every enemy of human health.

A gipsy family camped on the outskirts of a country town is taken sick with what is suspected to be typhus fever. The Service details an officer to study the cases and endeavor to discover the cause. Intestinal trouble breaks out in an industrial plant. The Service makes an investigation and discovers typhoid fever, and the necessary steps follow for its extermination. Trachoma is present among the school children in some locality; a surgeon is sent to investigate the disease and advise measures for its control. Influenza sweeps like wildfire across the country. The resources of the Service are mobilized to meet the scourge. Lack of definite knowledge regarding the cause of this disease has as yet rendered inefficient any efforts for its control. The Public Health Service was aware of the danger before it came but was powerless to prevent it, as influenza is not a quarantinable disease. The spread of the disease was so rapid and extensive that doctors and nurses in every community were overtaxed, most places finding themselves without a sufficient number, especially as so many were enlisted in the army. To meet this difficulty a special appropriation of \$1,000,000 was passed by Congress, and the Service, together with the Red

Cross and local health organizations throughout the country, organized, as best they could, a temporary corps of doctors and nurses, which were sent to points of greatest need. Meantime data were being gathered by means of a house to house canvas in certain chosen localities, in the effort to ascertain the factors involved in the spread of the disease. Laboratory studies were made on the possibility of transferring the disease from man to lower animals and from man to man, but no definite information obtained except as to the difficulty of the artificial transfer of the disease. Tests were also made of several anti-influenza and pneumonia vaccines, but with no very satisfactory results.

These few instances, which could be multiplied many times, will illustrate the work which is being done by the Service in the study and control of disease in the United States.

In this work it employs not only fixed laboratories, but laboratories on wheels, having two cars, which can be sent to any point for a study of disease in the field, as occasion arises.

The determination of the cause of pellagra, a disease of faulty nutrition, of which mention has been made in a previous chapter, is largely due to the work of Goldberger, one of the Service Staff.

When the youth of our nation were concentrated by the hundreds of thousands in army camps, the Service was called upon to protect them from disease in the extra-cantonment areas. Within the camps themselves the army was responsible for their protection, but in the regions about the camps, especially in the towns and amusement centers visited by the men when on leave, the responsibility fell upon the Public Health Service, aided in many cases by the Red Cross.

Realizing the terrible menace of venereal diseases, and under the stimulus of patriotic enthusiasm, Congress in 1918 established a Social Hygiene Board for the study and control of these diseases, consisting of the Secretaries of War, Navy, and Treasury and the Surgeons-General of War, Navy and Public Health Service or their representatives, and appropriating nearly \$2,000,000 annually for carrying on the work. The administration of this act has been largely in the hands of the Public Health Service, which by co-operation with state boards of health in the establishment of clinics for the treatment of venereal patients, by the establishment of an interstate quarantine against infected persons, restricting their privileges of travel from state to state, and by means of a widespread campaign of education has made a splendid start in the battle against these social plagues.

In the field of industrial hygiene the Service work looms large. When we realize that to change one employee in a

factory or store costs the employer from \$35 to \$70, we appreciate the importance of the worker's health from the standpoint of dollars and cents alone. Add to this the danger of the crowded factory as a center of contagion and consequent menace to an entire community, and we can realize the necessity of industrial hygiene as a public measure. During the recent war this work became even more than usually imperative, for the city of ordinarily 20,000 or 30,000 was suddenly swelled to one of 100,000 or more. The housing problem became acute and with it arose the even more serious ones of water supply, sewage disposal and of all the factors which make for health or disease in any community. Then too the great munition factories, ship-building plants, and all the other war activities sprang up like mushrooms over night, bringing with them teeming life in new locations and consequent menace to the public health, and increasing the opportunities as well as the responsibilities of the men of the service.

If we drink water, and most of us do nowadays by virtue either of choice or necessity, we will be interested to know that when we travel on a train from one state to another our drinking supply is safeguarded by the watchful care of the U. S. Public Health Service. These supplies are under constant supervision by agents of the Service, and if they do not meet the standard set they are condemned and the carriers obliged to improve them or obtain new supplies elsewhere.

In addition to a station in Hawaii for the study and treatment of lepers, whose investigations in the treatment with derivatives of chaulmoogra oil, are meeting with a considerable degree of success, the Service has established a national home for lepers in the United States, a number of which unfortunate people live among us.

The Service also maintains a tuberculosis sanitarium at Fort Stanton, N. M., and numerous hospitals for the care of sick or disabled soldiers, sailors and other government employees.

One might continue indefinitely to rehearse the activities of the U. S. Public Health Service, not to mention those of the many other agencies for protecting public health, but the foregoing must suffice as a bird's eye view of this great and ever-growing field.

In all the great work which biology has done for man there is none more splendid than its service in the field of preventive medicine.

CHAPTER XVII

The outlook. Some unsolved problems of biology. Possibilities of larger service.

It is as profitable for Science as for the individual to pause now and then and take an inventory; to view in retrospect its successes as well as its failures, and in prospect its possibilities and its problems—such a backward glance over the pages of biology in America has been taken in the preceding chapters. In closing let us draw aside the veil for a moment, and view the opportunities for future service of biology to man.

The most urgent demand upon biology today is for a study of the factors of evolution. In spite of Darwin, Weismann and DeVries and the host of splendid workers who have devoted their lives to a solution of this problem in the past, the final answer, or answers, for there are doubtless many, is still shrouded in mystery. The ultimate causes of variation, the creative power of selection, the possibility of the inheritance of characters acquired during the lifetime of the individual—these and many others are still unsolved problems.

Closely allied to, nay, inseparable from the problem of evolution is that of inheritance. Is the "unit-character" the Ultima Thule of the explorer of life's mysteries? Or is it in itself a little cosmos of characters acting and reacting upon one another to produce the end result? Is the behavior of "unit characters" fixed and immutable, like the laws of the Medes and Persians, or is it subject to environmental influence, yielding different results according to the conditions imposed upon it? And what is the nature of the "determiners" of these "unit characters"? Are they constant physical or chemical entities, persistent from generation to generation of the cell, or are they variables, which pass through a complex series of developmental changes beginning in the fertilized egg and reaching fruition only in the adult organism? Are these determiners restricted to the chromosomes or are they present in the cytoplasm as well? And if restricted to the former does the latter exercise no influence upon them? Is the entire organism a complex of unit characters, or is it the superficial characters alone, such as color,

size, hair form, etc., which behave as units in inheritance? Is sex purely an inherited character, subject to Mendelian laws, or is it determined by conditions of metabolism or otherwise, and if so is it subject to experimental control? And what is the significance of the curious sex intergrades which have recently been described, and which are "neither fish, flesh, nor good red herring"? How and why did sex arise? There are some animals, such as Hydra, which reproduce both sexually and asexually. What are the factors inducing sexual reproduction in such forms? And what is its function? Does it exercise a rejuvenating influence upon the race, or does it serve to produce variation and thereby lead to evolution and adaptation? Or do both of these, or yet other explanations contain the truth?

Why do some animals reproduce by parthenogenesis at one period in their life history and sexually at another? And what is the significance of parthenogenesis, which in some cases has gone so far that males are extremely rare, and may possibly in some species have disappeared entirely? At any rate if they occur, they are yet to be discovered.

Surrounded as we are by speculation and uncertainty in the realm of evolution and inheritance, we enter a veritable *terra incognita* when we come to speculate upon the essence of life itself. Is life purely a physico-chemical process, and the organism a mere machine controlled by forces extraneous to itself? And if so, what are the physico-chemical reactions which constitute life? Or is life a process outside the realm of physics and chemistry? Are our concepts of consciousness and intelligence, of volition and of soul, realities, or mere figments of the imagination? Or is there yet some middle course which we may steer between the Scylla of "mechanism" on the one hand and the Charybdis of "vitalism" on the other?

If life be an unsolved problem, equally so is the cessation of life or death. Is death inherent in life or was life primarily unending, and death secondarily derived from factors outside of life itself? And what of the origin of life? Is Harvey's dictum "*Omne vivum ex vivo*" necessarily true? Or may lifeless matter to-day be generating life and continue to do so throughout the ages, as it did at some time in the past?

If we are some day to solve the riddle of life, we shall then be able to create life. While some enthusiasts have from time to time claimed that they have done this, their claims are yet unsubstantiated, but the possibility of such an achievement looks less remote to us today, than would have seemed the Röntgen ray or the wireless telegraph to our forefathers.

Much as we have already learned regarding the structure of the cell, it is but as a drop in the bucket compared with our ignorance of this marvelous mechanism of life. What is the origin of the nucleus? Is it primary and the cytoplasm formed from it, or *vice versa*. Or yet are both nucleus and cytoplasm, co-ordinate parts of the cell in time as well as in function? Do such apparently anucleate cells as the bacteria and the blue-green algæ contain nuclear material, and if so what is its condition in these cells, and is such a condition primary or derived? If primary, how has a definite nucleus arisen in higher cells? Is the distributed nucleus as we find it in certain Protozoa a step in this direction, or is this in turn a specialized condition derived from the more generalized one in which but a single nucleus occurs within the cell? Similarly how has the green coloring matter of the majority of plants and a few animals been evolved, what is its chemical composition, and by what physico-chemical processes does it utilize the sunlight in building up the complex starches and sugars from carbon-dioxide and water?

Our existing knowledge of the cell has been obtained mainly from fixed and stained material. Does such material tell us a true story? What of the living protoplasm—its physical structure and chemical composition? And what of the wonderful cell products known as ferments, which play so large a rôle in all processes of life? What is their chemical character, and in what way do they do their remarkable work?

What are the factors regulating the growth, and determining the size of organisms? What enables them to regenerate lost parts? And why does regeneration in some cases reproduce the part lost, and in others a wholly different one?

In medical biology, great as have been the advances of the past, yet greater still may be the progress of the future. When Christ said to his disciples, "Among them that are born of women there hath not risen a greater than John the Baptist: notwithstanding he that is least in the kingdom of Heaven is greater than he,"¹ he clearly referred to the blessings conferred upon men by the coming of that kingdom. While it is scarcely possible to conceive of discoveries of greater value to mankind than those made by Pasteur, nevertheless "he that is least in the kingdom (of modern sanitation) is greater than he." By the application of the discoveries of a Pasteur, Metschnikoff and Koch or Flexner is it chimerical to dream of a future world from plague set free? There is much remaining to be done however and none need complain that the Golden Age of Discovery has vanished, and that the frontier in biology exists no more. The filter-

¹ Matthew xi, 11.

able viruses, those disease-forming organisms so minute that they can pass through the pores of the finest filters, yet remain to be isolated; the cause of cancer, and many other diseases to be discovered, and the functions of the ductless glands more clearly determined than they are at present. These are a few of the more urgent tasks which the medical biologist has before him today.

The palæontologist still has awaiting him untouched areas of the earth's surface, where may lie concealed the key to many a riddle regarding the evolution and relationships of animals and plants, and their distribution in past and present time.

The embryologist may aid the palæontologist in his studies of animal phylogeny by describing the embryology of many of the rarer, and as yet unstudied forms, while the comparative anatomist is partner to them both in solving the problems of animal descent.

Manifold are the unsolved problems relative to the life histories, distribution, and economic relations of animals and plants. Which are our friends, and which our foes, how best can the former be protected and propagated, and the latter exterminated, and what new sources of wealth can biology discover for mankind?

With such a job on its hands, and the foregoing outline is but a glimpse of its burden, how best can biology "carry on"? Helpful and encouraging as is the endowment of great institutions such as those founded by a Rockefeller or a Carnegie, the establishment of research chairs, and equipment of laboratories in our universities, and the devotion of government bureaus to biological research; nevertheless the hope of biology is in its followers. "God give us men," is now as ever the prayer of progress. The spirit of Agassiz must still fill our laboratories, or their equipment will represent but so much waste of money and of effort.

But the spirit of investigation needs both encouragement and guidance. It is indeed true that investigation is its own reward, but in the keenness of the social struggle for existence the young man or young woman of today is not likely to choose a calling which has glory for its sole reward. He is too likely to recall the words of Gray anent "the paths of glory." If our research institutions are to secure the best men they must offer sufficient inducement to at least provide for the ordinary needs of life and enable the research workers to enjoy some of its pleasures. Herein lies the need for the liberality of wealth toward science. Otherwise science is bound to become commercialized and turned to purely economic ends. Another great need of biology is unification of effort. Co-operation in biology is not lacking today, but co-ordination of effort is conspicuous chiefly by its absence. A dozen

men in as many places may each be working on the same problem, wholly oblivious of the work of the others. Our journals and societies do indeed serve as channels of communication between workers, but usually not until their problems are well under way, or perhaps completed. Might not these societies, through committees appointed for this purpose, serve to at least put workers along similar lines in closer touch with one another than they are at present? Such a suggestion is not new, but so far as the writer knows, it has not yet received sufficient consideration:² To attempt to direct research in the sense of limiting individuals in their choice of problems, would have a deadening, if not deadly effect on all scientific progress. But guidance along the line of co-ordination of effort should be as stimulating as the other would be depressing.

Might not institutions also combine with advantage in the prosecution of special researches? A striking and salutary example of such co-ordinated effort between governments was afforded by the International Council for Investigation of the Sea, prior to the great war, whose work has been mentioned in a previous chapter. It was organized in 1902 to eliminate waste of effort and of money in the study of the physics, chemistry and biology of the ocean and its economic resources. While each government prosecuted its own researches in its own territory, all of the results were turned in to the central office at Copenhagen for collaboration and publication, and the general plan of the investigations was outlined by a central committee chosen from representatives of all the governments concerned. By means of this co-ordination results of great scientific and economic importance were achieved, with material saving of time and effort.

It would appear both feasible and desirable to effect a similar co-ordination of effort in our own country. On our western coast for example are several institutions engaged primarily in a study of the biology of the Pacific Ocean. Why might not these institutions combine; and, with the aid of the U. S. Bureau of Fisheries, prosecute this research in a systematic and comprehensive way, rather than in the present sporadic and disjointed fashion?³ Why also might not the

² The establishment of the National Research Council during the war was a step in this direction.

³ Looking toward such an end, a conference was held at Honolulu in August, 1920, under the auspices of the Bishop Museum, which was founded in 1889 by the late Charles Reed Bishop of New York, for the study of the natural history and ethnology of the Pacific islands. The Museum was a memorial by Mr. Bishop to his wife, who was Princess Bernice Pauahi, great grand-daughter of the Moi of Hawaii when Captain Cook visited the islands. The Museum is now co-operating with Yale University in the exploration of the Pacific and several other institutions are also interested in the project.

life of our inland waters be studied in a similar comprehensive and connected manner, by the several aquatic biological stations working under the general direction of the Bureau of Fisheries? Or is our American science so sectarian in character that co-ordinated effort is impossible?

Today American biology is preëminent. Its growth and achievement in the past have been phenomenal. But yet greater possibilities lie before it, in the coming reconstruction of the world.

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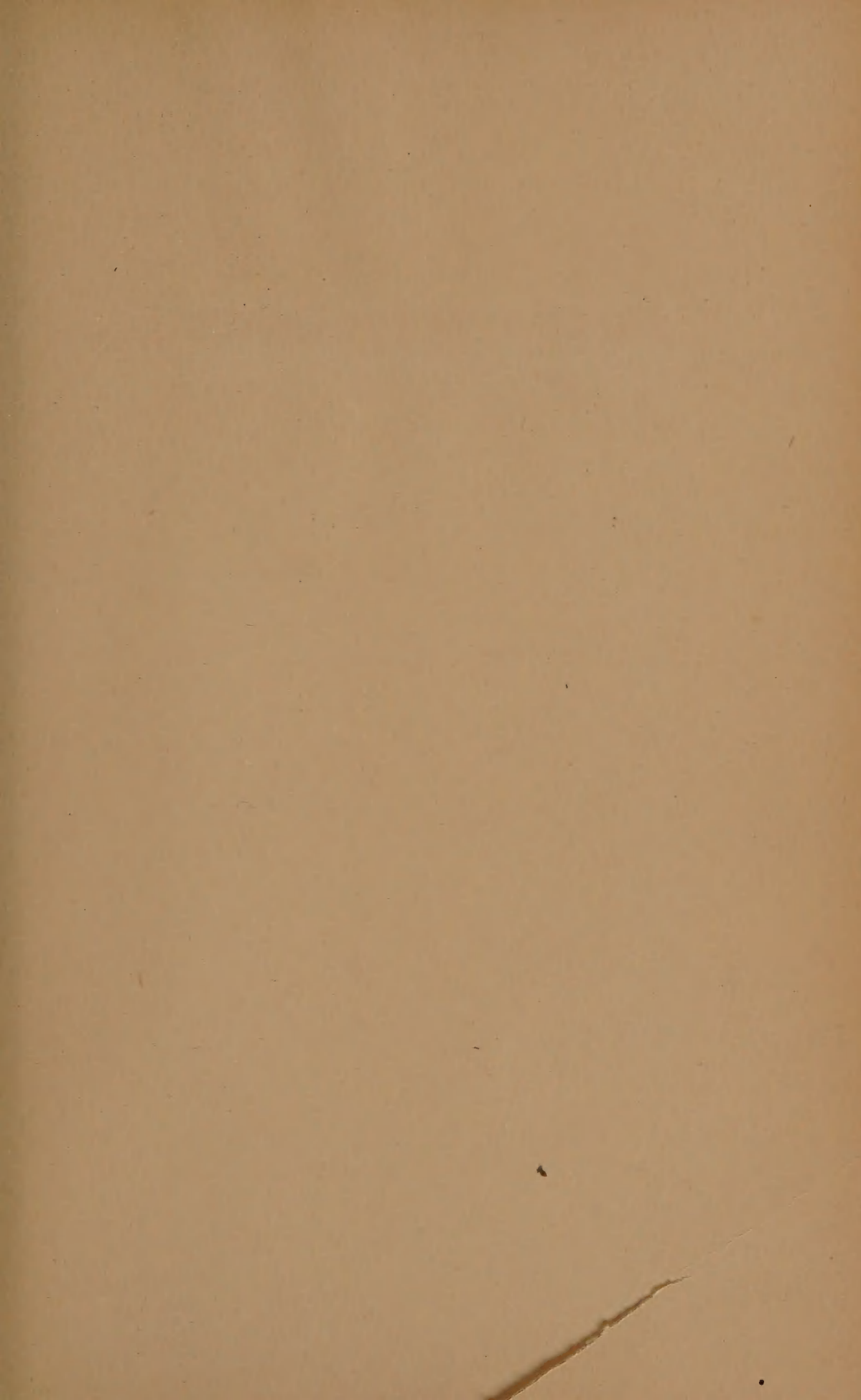
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